THE FOUNDATIONS OF NUTRITION

BY

MARY SWARTZ ROSE

H. Chick. 1938

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Antoine Laurent Lavoisier

(1743-1794)

The Father of the Science of Nutrition

The portrait is reproduced from the London Encyclopedia 1812

THE FOUNDATIONS OF NUTRITION

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PREFACE

Any one can learn to run an automobile by rule. "Turn on the gas, start the engine with clutch in neutral, release the brake" has been mastered by hundreds of thousands who know very little about electricity or theories of mechanics; who never pause to consider how the battery starts the motor or how the gasoline is converted into power. Nevertheless, great numbers of automobile owners have found it to their advantage to study the mechanism of their cars because it saves money in upkeep and repairs; it often saves time in waiting for some one to help in an emergency; and it may save much strain on the car, prolonging its life and increasing its period of service.

Much the same can be said of the human machine. Everybody knows that food is required to run it, but the appetite is such a reliable "self-starter" for food consumption that no one has to be taught what to do with a plate of attractive viands. Like running an automobile, eating can be done by rule of thumb, without any understanding of what the food is doing to the body beyond the passing pleasure of the meal; or it can be managed with intelligence and foresight, avoiding in course of time many disabilities and saving the body unnecessary wear and tear, which insidiously but inevitably cut down its efficiency and impair the value of the individual to himself and to society.

This book is written for those who wish to live more intelligently. An effort has been made to present within a small space some of the fundamental principles of human nutrition in terms which call for no highly specialized training in those natural sciences upon which the science of nutrition rests. The selection of topics and the relative amount of space devoted to each are based on much ex-

perience in presenting the subject of nutrition to beginners whose object is to be well informed as to the significance of food in daily life so that they may order their own lives more successfully and may have a better understanding of the part which nutrition plays in health in the world at large.

Each essential factor in an adequate diet is discussed in detail with many references to animal experiments which help to make clear the reasons why it must have a place in the daily program. The foods which serve best as sources of these essentials have been indicated, and a very practical method of comparing foods on the basis of how much of a given dietary essential can be obtained from each in relation to the total day's requirement. It is hoped that the new, colored illustrations will make these comparative values more vivid.

In preparing this third edition it has been gratifying to note that in the main the researches of the past five years have only served to establish more firmly the foundations of nutrition as originally outlined in 1927. At the same time, it has been necessary to make a thorough revision of every topic because there have been many additions to our knowledge of every dietary essential. These new advances enable us to understand human requirements better and to use our common food materials to increasingly good advantage. In 1933 only three of the vitamins had been crystallized and in case of only two had any clear picture of chemical structure begun to emerge. In this edition it is possible to state not only that six have been crystallized and chemically identified, but also that three of them have been prepared artificially. The use of highly concentrated preparations or of pure crystals has helped to advance rapidly our understanding of the functions of the vitamins and great activity in the assay of foods for vitamin values has furnished a mass of data, necessitating complete revision of all tables and dietaries.

The reading references at the end of each chapter have been chosen for their availability and clearness. Throughout

the text some references to original investigations have been included as footnotes, for the sake of those who wish to get a little more of the experimental point of view. For those wishing to make a more comprehensive study, Sherman's *Chemistry of Food and Nutrition* is available, with ample references on all aspects of the subject.

The author wishes to express her very great appreciation of the valuable criticism received from Professor Henry C. Sherman and her thanks for many helpful suggestions from Professor Grace MacLeod and Doctor Clara M. Taylor.

Grateful acknowledgments are also due Dr. Ella McCollum Vahlteich, to whose good judgment and painstaking care the completeness and accuracy of the tables and dietaries are to be attributed; and to Miss Patricia Houghton and Mrs. Charlotte M. Herter for their help in the preparation of the manuscript. To those who have so kindly aided with the illustrations the author would also acknowledge her great indebtedness and appreciation of their courtesy.

M. S. R.

New York City
January, 1938

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THE FOUNDATIONS OF NUTRITION

CHAPTER I

HISTORICAL INTRODUCTION

Section 1

SOME LANDMARKS IN THE DEVELOPMENT OF THE SCIENCE OF NUTRITION

The idea that there is a close connection between man's diet and his well-being is no innovation of the twentieth century. In an ancient chronicle we may read: "In the third year of the reign of Jehoiakim, king of Judah (607 B. C.) came Nebuchadnezzar, king of Babylon, unto Jerusalem, and besieged it." When the city fell into his hands, the king ordered that certain noble youths, "well-favored and skilful in all wisdom," be selected for training as courtiers. They were to have a special education and a daily portion of the king's meat, and of the wine which he drank. Living a carefully prescribed life, at the end of three years they would presumably be fit to stand before the great monarch. One of these youths "with knowledge and skill in all learning and wisdom" objected to the dietary part of the program and purposed in his heart that he would not eat the king's meat nor drink his wine; but the prince of the eunuchs, who had him in charge, protested, saying, "I fear my lord the king." The young man countered with a reasonable proposal: "Prove thy servants, I beseech thee, ten days; and let them give us pulse to eat and water to drink. Then let our countenances be looked upon before thee, and the countenance of the youths that eat of the king's meat." This seemed a fair bargain and so the nutrition experiment was undertaken, with the result that at the end of the ten days "their coun-

tenances appeared fairer and fatter in flesh than all the children which did eat the portion of the king's meat. So the steward took away their meat and the wine which they should drink and gave them pulse;" and when at the end of their probationary period the king examined them they passed with a score ten times better than all the magicians and enchanters in his realm.[1]

What Becomes of Food Eaten?

From that time to this, man has given much thought to the problem of where food goes when it is eaten and what it does to the one who eats it. But for many centuries the answers to such questions were philosophical rather than scientific. The greatest philosopher among the ancients with regard to food was Hippocrates, the famous priest of Æsculapius officiating in the celebrated Health Temple of Cos in Greece in the day of Socrates and Plato, who by his wisdom and skill earned the title of Father of Medicine. The historian Strabo says that he was trained in dietetics, and some of his aphorisms have a modern sound, for example: "Growing bodies have the most heat; they therefore require the most food, for otherwise their bodies are wasted. In old persons the heat is feeble and therefore they require little fuel, as it were, to the flame for it would be extinguished by much." (Aphorism 14.) [2] But Hippocrates and his successors for two thousand years accounted for the disappearance of food as "insensible perspiration" and "heat" without any real understanding of what either term meant.

In 1614 A. D. a university professor with a practical turn of mind devised a chair connected with a steelyard to weigh himself before and after meals, so that he might find out the amount of this "insensible perspiration," for he said: "He only who knows how much and when the body does more or less insensibly perspire will be able to discern when or what

[1] *Daniel* I:1–15.

[2] Adams, Francis. *Genuine Works of Hippocrates,* page 197. William Wood and Co. (1891).

is to be added or taken away, either for the recovery or the preservation of health." (Aphorism 3.)[1] Even Sanctorius's painstaking efforts did not solve the mystery because in his day there was no science of chemistry. This did not begin its active development until about half a century later.

Fig. 1.—Sanctorius on the Steelyard Which He Devised to Weigh Himself before and after Meals.

Air Is Essential for Life

In 1627 was born the Honorable Robert Boyle, seventh son of "the great Earl of Corke," destined to receive the best education of his day in England and on the continent and to become known to every student of chemistry or physics as a result of his studies on the "weight and spring of the air." In the course of his extensive investigations of the properties of the air, he conducted a large number of "pneumatical experiments about respiration." He put into the receiver of his "pneumatical engine" all sorts of small animals—"a kitling newly kittened," "a duckling that was yet callow," "a large and lusty frog"—to find out "whether there reside in the heart of animals such a fine and kindled, but mild substance, as they call a Vital Flame, to whose preservation, as to that of other flames, the Air (especially as is taken in and expelled again by respiration) is necessary," and he found that it was necessary, as the following experiment will serve to indicate:

"Experiment I. We included in a round vial with a wide neck (the whole glass being capable of containing about 8 ounces of water) a young and small mouse, and then tied strongly upon the upper part of the glass's neck a fine thin

[1] Lusk, Graham. *Science of Nutrition*, 4th edition, page 18. W. B. Saunders Co. (1928).

bladder, out of which the air had been carefully expressed, and then conveyed this phantastical vessel into a middle-sized receiver, in which we also placed a mercurial gage (adjusted by our elsewhere mentioned standard); this done, the air was by degrees pumped out, until it appeared by the gage, that there remained but a fourth part in the external receiver (as for distinction sake I call it) whereupon the air in the internal receiver expanding itself, appeared to have blown the bladder almost half full, and the mouse seeming ill at ease by his leaping, and otherwise endeavoring to pass out at the neck of his uneasy prison; we did, for fear the over thin air would dispatch him, let the air flow into the external receiver, whereby the bladder being compressed, and the air in the vial reduced to its former density, the little animal quickly recovered." [1] So this ardent chemist demonstrated to his full satisfaction the dependence of animals upon the air they breathe for life.

Still more significant respiration experiments were made by a young chemist named John Mayow, who came under the influence of Boyle and in 1668, at the age of twenty-eight, published a "Treatise on Respiration" in which he showed that if a burning candle and an animal be put together in a bell jar both will expire sooner than either one alone. Mayow seems to have been the first to recognize that breathing brings the air into contact with the blood. He wrote: "Air loses somewhat of its elastic force during respiration by animals as also in combustion. One must believe that animals, like fire, remove from air particles of the same nature." [2] Mayow's death at the age of thirty-four delayed the development of true conceptions of respiration for nearly a hundred years.

The Gases of Respiration

In 1754 a young Scotchman named Joseph Black, who was studying medicine at the University of Edinburgh, published

[1] *Works of Robert Boyle*, Vol. 3, page 128. A. Millar (1744).

[2] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 10. D. Appleton and Co. (1922).

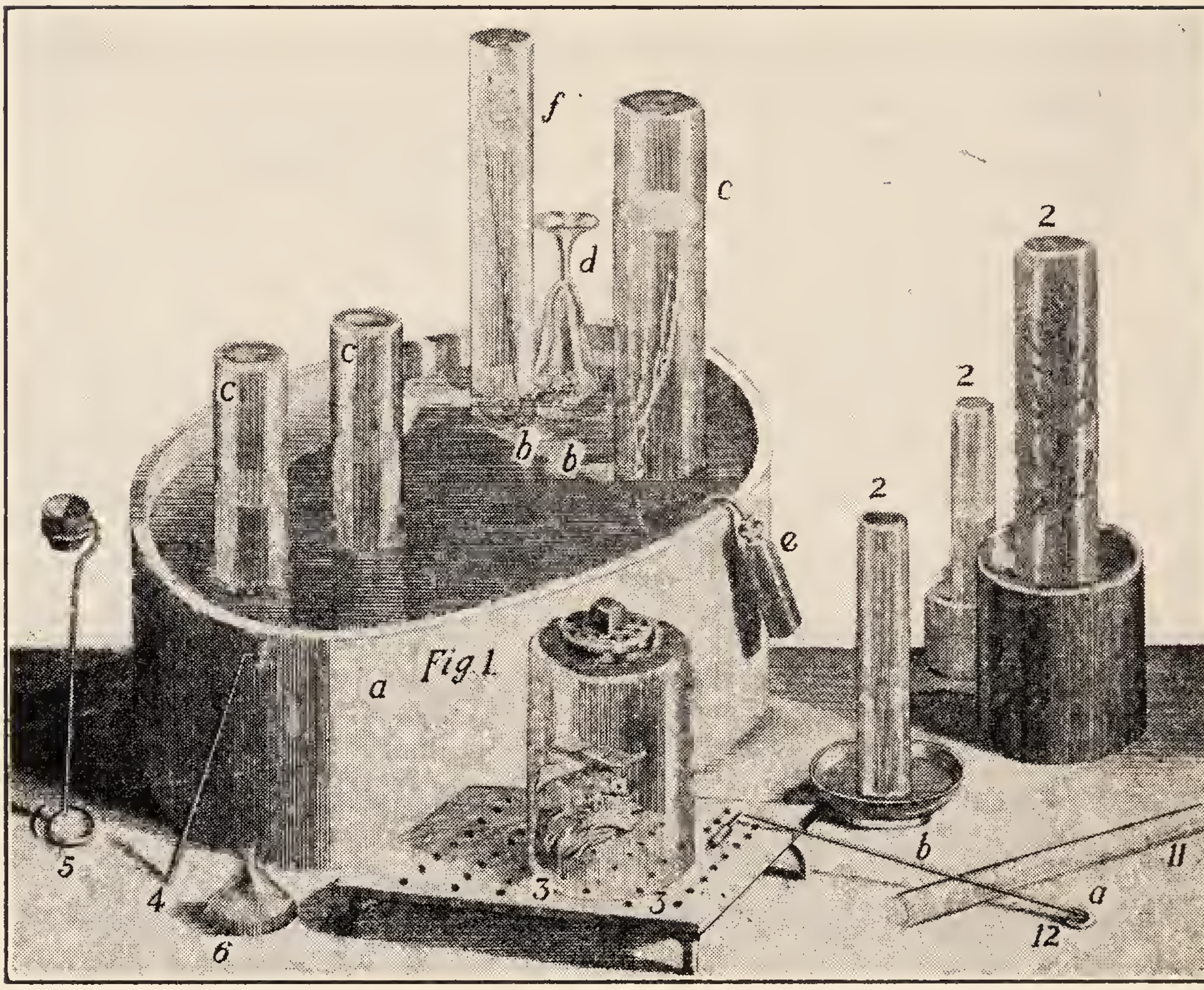
his inaugural dissertation for his M. D. degree on the subject of magnesia and quicklime; substances in which he was specially interested because the medicines in vogue for the cure of gallstones all seemed to derive their efficacy from quicklime. He had discovered that a cubic inch of marble yielded about half its weight of pure lime and "as much air as would fill a vessel holding six wine gallons." His lectures were published after his death from his manuscript notes, and his biographer wrote in the preface: "It was not only a most unexpected and curious thing to find that a matter so solid and impenetrable as marble could appear in the form of air, and this air be again put into our hands in the form of marble; but this new acquaintance had properties which forcibly called for the most serious attention. This air can be poured from one jar into another like as much water; and when it is poured out on a candle, or even on a fire in sufficient quantity, they are extinguished in an instant, as if water had been poured on them. . . . It has also been discovered that this air, so destructive and salutary, is forming in vast quantities every moment around us." [1] He called it "fixed air," a little later to be identified as carbon dioxide. He also found that limewater was made cloudy by breathing into it through a tube, as well as by shaking it in a jar in which a candle had just gone out, and concluded that the breathing of animals changes "common air" into "fixed air."

While Black was winning renown as a professor in the University of Edinburgh and a devoted following as a practicing physician in the city, a dissenting clergyman in England, by the name of Joseph Priestley,[2] was earning his living by acting as librarian for a rich patron but devoting all his spare time to chemical experimentation.

Priestley took a living plant (a sprig of mint) and put it into a closed receptacle in which a candle had already burned

[1] Lectures on the Elements of Chemistry, delivered in the University of Edinburgh by the late Joseph Black, M. D., Professor of Chemistry in that University. Published from his manuscripts by John Robinson (1807).

[2] He was born in Yorkshire, March 13, 1733, and came to the United States on June 4, 1794, living in Northumberland, Pennsylvania, until his death on February 6, 1814. His burning glass is preserved in the museum of Dickinson College, Carlisle, Pennsylvania.



(*Courtesy of the New York Public Library*)

Fig. 2.—Apparatus Used by Priestley.

Plate 1 and description from *Experiments and Observations on Different Kinds of Air* (1790).

"I first used an oblong trough made of earthenware, Plate 1, Fig. 1, about 8 inches deep, at one end of which I put some flat stones, about an inch or half an inch, under the water, using more or fewer of them according to the water in the trough. I afterwards found it more convenient to use a larger wooden trough of the same form, with a shelf about an inch lower than the top, instead of the flat stones above mentioned. In one end of this trough are ledges on which it can slide. . . . The several kinds of air I usually keep in cylindrical jars, as *c*, *c*, Plate 1, Fig. 1, about 10 inches long, and $2\frac{1}{2}$ inches wide. . . . If I want to try whether an animal will live in any kind of air, I first put the air into a small vessel, just large enough to give it room to stretch itself; and as I generally make use of mice for this purpose, I have found it very convenient to use the hollow part of a tall beer-glass, *d*, Fig. 1, which contains between two and three ounce measures of air. In this vessel a mouse will live 20 minutes or half an hour. . . . In order to keep mice, I put them into receivers open at the top and bottom, standing upon plates of tin perforated with many holes, and covered with other plates of the same kind, as Plate 1, Fig. 3. . . . In the same manner in which a mouse is put into a vessel of any kind of air, a plant, or anything else may be put into it, viz., by passing it through the water. . . . When I want to try whether any kind of air will admit a candle to try to burn in it, I make use of a cylindrical glass vessel, Plate 1, Fig. 11, and a bit of wax candle, *a*, Fig. 12, fastened to the end of a wire, *b*, and turned up in such a manner as to be let down into the vessel with the flame upwards."

out. After several days another candle was introduced into the same jar and this time it did not go out but burned brightly. Soon after this, he took a jar, filled it with mercury, and carefully inverted it in a vessel containing mercury, so that no air entered the jar. He then introduced through the opening, under the mercury, some red oxide of mercury, which rose and floated on top of the mercury inside the mouth of the jar. Upon this he converged the heat of the sun by means of a powerful burning glass, and this is how he described the result: "I presently found by means of this lens air was expelled from it (the mercuric oxide) very rapidly. Having got about three or four times the bulk of my materials, I admitted water and found that it was not imbibed by it. But what surprised me more than I can well express was that a candle burned in this air with a remarkably brilliant flame." [1] Priestley had discovered a new gas, given off by the growing plant and by the heated mercuric oxide, which the candle flame fed upon so readily.

Fig. 3.—Scheele's Apparatus Showing Bees in the Upper Chamber of a Glass Apparatus Filled with Oxygen.

At almost the same time a similar experiment had been performed by a Swedish apothecary named Scheele, who called the gas which he had discovered "fire air." Scheele next took two bees, put them in a chamber with a little honey, connected the chamber with a glass cylinder filled with the "fire air," and immersed its lower end in limewater. Day by day the limewater rose in the tube and the volume of this gas diminished, until at the close of a week the limewater nearly filled the cylinder and the bees were dead. The "fire air" had been used up by the bees and the carbon dioxide given off by them was absorbed by the limewater which filled the space originally occupied by the "fire air."

[1] Priestley, Joseph. *Experiments and Observations on Different Kinds of Air*, Vol. 2, page 107. Thomas Pearson (1790).

(From a drawing by Mme. Lavoisier)

FIG. 4.—Lavoisier in His Laboratory Making the First Measurements of Energy Expenditure by a Human Being.

Respiration a Measure of Food Burning in the Body

Priestley and Scheele were both in communication with a brilliant young French nobleman, Antoine Laurent Lavoisier, a member of the French Academy of Science. At their urgent request, he repeated their experiments, confirming the discovery that "fixed air" was carbon dioxide and giving to "fire air" the name of oxygen. Lavoisier then proceeded on his own account to demonstrate how living animals affect the air. He took a sparrow, shut it up in a small chamber and concluded from his observations that oxygen disappeared from the air and that after the animal had died the carbon dioxide which it produced could all be absorbed from the chamber by limewater. Then Lavoisier and the great physicist Laplace together took another step forward. They put a guinea pig into a chamber and measured for ten hours the carbon dioxide formed by its respiration. This was found to equal that produced by burning in a closed vessel 3.33 grams of carbon. Next the guinea pig was confined for ten hours in a chamber containing a known weight of ice, and the quantity of ice melted by the animal's body was determined. This required for its melting almost exactly the same amount of heat as was evolved in burning the 3.33 grams of carbon. The obvious conclusion was that the carbon dioxide formed by the guinea pig came from burning in its body the equivalent of 3.33 grams of carbon.[1]

Similar observations were subsequently extended to human subjects, and drawings made by Mme. Lavoisier from memory after her husband's death in 1794 show Lavoisier's associate, Seguin, sitting in a chair breathing through a mask into a series of globes by means of which the oxygen consumed and the carbon dioxide given off were measured. Lavoisier came to the conclusion that "respiration is only a slow combustion of carbon and hydrogen, which is similar in all respects to that which takes place in a lamp or lighted candle; and from this point of view the animals which respire

[1] A slight discrepancy was accounted for in the reduction of the guinea pig's body temperature by the cold.

are truly combustible bodies which burn and consume themselves."[1] Because of his grasp of the significance of the respiratory process in relation to food, Lavoisier is accounted the father of the science of nutrition.

SECTION 2

METHODS AND APPARATUS FOR THE MEASUREMENT OF ENERGY TRANSFORMATION IN THE BODY

Ice and Water Calorimeters

Lavoisier was the first investigator who applied the balance and the thermometer to the study of vital phenomena. His

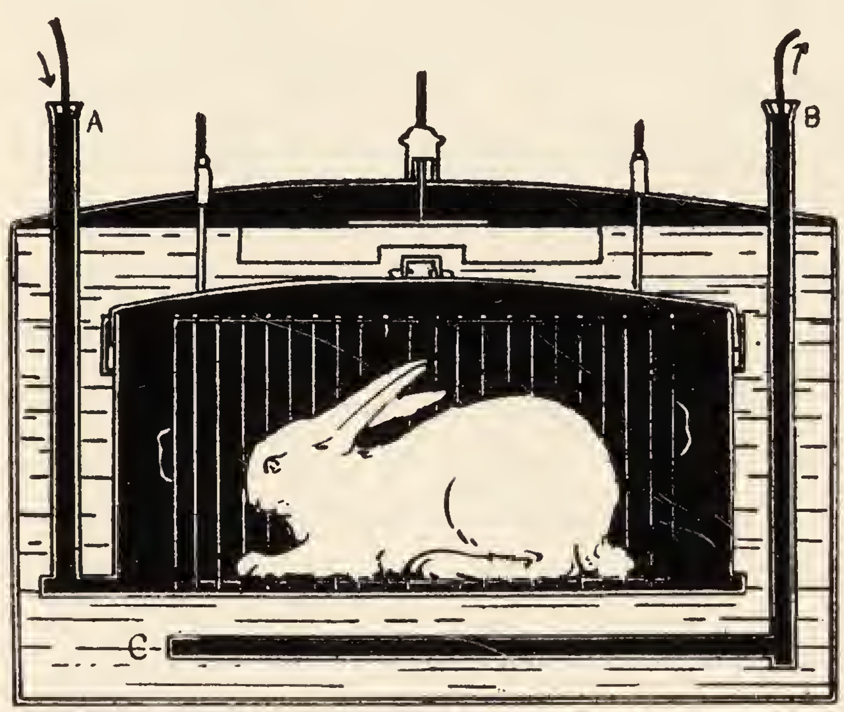


FIG. 5.—A Water Calorimeter of 1823.

The inner chamber containing the animal was submerged in a larger receptacle filled with water. Air entered at A, circulated through a coil under the inner chamber, and connected at C with the exit pipe B. Thermometers extending into the water recorded the rise in temperature caused by the animal.

work with Laplace on the measurement of the heat production of a guinea pig has already been mentioned; the ice calorimeter which they devised for this purpose is still preserved in Paris. After Lavoisier's death the French Academy offered a prize for further investigation and two young men, Dulong and Depretz, entered the lists. They improved upon Lavoisier's methods, putting small animals into a chamber surrounded by water to absorb the heat and weigh-

[1] Cited by Mathews, A. P. *Physiological Chemistry*, 5th edition, page 287. William Wood and Co. (1930).

ing the carbon dioxide and the water given off from the animals' bodies. Dulong won the prize (1823), although Depretz's work appears now to be somewhat superior.

The Measurement of Respiration

In 1849, Regnault, professor of physics at the University of Paris, with his assistant, Reiset, constructed an apparatus which enabled him to keep small animals respiring normally

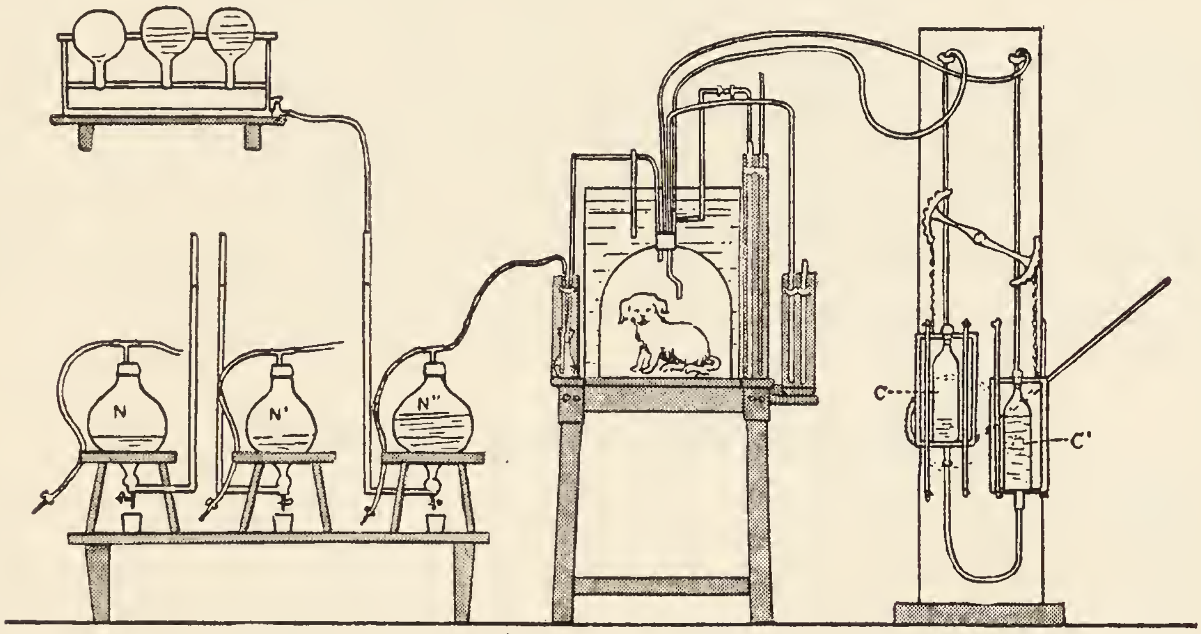


FIG. 6.—Respiration Apparatus of Regnault and Reiset.

Oxygen was supplied to the animal from a large flask, N″. (N and N′ are other flasks in reserve.) Water pressure from the flasks above at the left drove the oxygen into the apparatus. An exit tube from the chamber containing the animal is connected with bulbs for absorbing carbon dioxide, C and C′. (From *Annales de Chimie et de Physique*, Series 3, Vol. 26, Plate III, 1849.)

in an enclosed space. The subject was placed in a glass case containing a known quantity of oxygen, which was replenished as it was consumed and the air in the apparatus was continually pumped through a solution which took out the carbon dioxide exhaled. By means of this device, Regnault was able to show that eating different kinds of food made a difference in the amount of oxygen used and in the amount of carbon dioxide excreted. He also noticed that the small animals absorbed more oxygen and produced more heat and more carbon dioxide in proportion to their size than did the larger ones—sparrows ten times as much as chickens; that cold blooded animals consumed less oxygen per unit of body weight than did warm blooded; and insects much more than

reptiles: for example, beetles consumed 0.96 liter of oxygen per kilogram per hour and silkworms 0.84 liter, while frogs and earthworms only about 0.10 liter. Regnault and Reiset hoped to study man in the same way, but the apparatus proved too expensive for them to construct.

The Nature of Body Fuel

Liebig, born at the opening of the nineteenth century, was the first to understand clearly that the substances oxidized in the body are organic carbon-bearing compounds of three types, protein, fat, and carbohydrate; and he showed that one gram of fat requires for complete combustion 2,050 cubic centimeters of oxygen, and one gram of starch 832 cubic centimeters—values nearly those in use today.

The Regularity of Heat Production

Bidder and Schmidt, two Germans working at the University of Dorpat (then in Russia), at about the same time (1850), concluded that for every species of animal there is a typical minimum of necessary metabolism, which is apparent in experiments when no food is given. "The extent of the respiration, like every other component of the metabolism process, is to be regarded as a function of one variable, the food taken, and one constant, a distinctly typical metabolism, which varies with the age and sex of the individual. This factor characterizes every animal of given race, size, age, and sex. It is just as constant and characteristic as the anatomical structure and the corresponding mechanical arrangement of the body." [1]

The First Respiration Chamber

Ten years later, Voit, then professor of physiology at the University of Munich, suggested to the physicist Pettenkofer, head of the hygienic laboratory of the city of Munich,

[1] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 63. D. Appleton and Co. (1922).

that he devise a respiration apparatus which would accommodate a fairly large dog. Pettenkofer aspired to work with men, however, so he constructed (1862) an air tight chamber as large as the stateroom of a steamer, in which a man could live with comfort. It was ventilated by means of pumps which drew air from the outside. The air was aspirated through the chamber, and at the point of exit samples were measured, after having been passed through suitable solutions for the removal of carbon dioxide and water.

These two men, Voit and Pettenkofer, working together with this apparatus established many points hitherto uninvestigated or obscure. Rubner, later one of the masters of the science of nutrition, found while working as a pupil in Voit's laboratory that the energy values to the body of starch and fat were equal to the heat produced by burning them in a special apparatus for heat determinations, called a calorimeter; but that the energy value of protein was different, since it could not be as completely burned in the body as it could in the calorimeter. The values which Rubner [1] established for protein, fat, and carbohydrate are still current, although figures derived by Atwater [2] from studies upon human beings seem more suitable for calculations such as are indicated in this book.

The Law of Conservation of Energy in the Animal World

Rubner became professor of physiology at Marburg and in 1892 in his own laboratory evolved a calorimeter large enough for a dog, which very accurately measured the heat production of the animal. This was connected with a Pettenkofer-Voit respiration apparatus, and the heat measured by the calorimeter exactly corresponded (within one per cent) to the heat calculated from the measurement of the oxygen intake, carbon dioxide output, and losses of energy-bearing

[1] One gram of protein, 4.1 calories; one gram of fat, 9.3 calories; one gram of carbohydrate, 4.1 calories.

[2] One gram of protein, 4 calories; one gram of fat, 9 calories; one gram of carbohydrate, 4 calories.

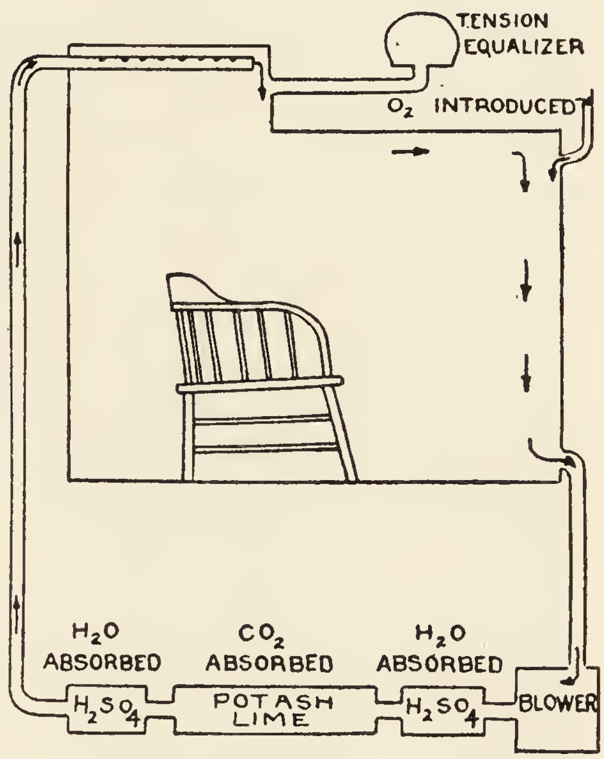
material in urine and feces. Thus, one hundred years after its initial conception by Lavoisier, Rubner established by animal experimentation the fundamental law that energy is neither created nor destroyed in the animal body.

The Respiration Calorimeter in America

While Rubner was engaged in these researches in Germany, Atwater, also at one time a pupil of Voit and later professor of chemistry at Wesleyan University, Middletown, Connecticut, began to work upon a respiration calorimeter which was brought to perfection in association with the expert physicist, Rosa. This calorimeter enabled him to carry out on man such experiments as Rubner was conducting on dogs. The respiration part embodied the principles of the Regnault-Reiset apparatus; the heat measuring part depended upon removing the body heat as fast as produced, by means of a current of cold water, thus maintaining a comparatively constant temperature in the chamber. Improvements were soon instituted by Benedict, and today the Atwater-Rosa-Benedict respiration calorimeter represents the highest perfection in this type of apparatus.

The apparatus consists of an air tight copper chamber surrounded by zinc and wooden walls with air spaces between. Gain or loss of heat through the metal walls of the chamber is prevented by keeping the zinc walls at the same temperature as the copper, so that there will be no exchange of heat between them. Provision is made both for heating the inner air space by electricity and for cooling it by water current. Protection is afforded by the outer air space against changes in the temperature of the air of the laboratory. Between the copper and the zinc walls are placed a large number of thermoelectric junctions connected with a delicate galvanometer by which each wall is tested every four minutes, day and night, during the progress of an experiment. There is no possibility of passage of heat through the walls of the chamber influencing the results. The ventilating air current is so regulated that there is no difference in the tem-

peratures of the incoming and the outgoing air. The heat evolved by the subject is mostly absorbed by a current of cold water passing through a pipe coiled near the ceiling of the chamber, although a small quantity leaves as latent heat of water vapor. The amount of heat removed from the chamber by the cold water passing through the heat absorbers is computed from the amount of water that flows through the pipe and its rise in temperature during its passage.



(*Courtesy of Dr. F. G. Benedict*)

Fig. 7.—Chair Type of Respiration Calorimeter.

The arrows show the circulation of the air, which is kept in motion by the blower. Water (H_2O) is absorbed by the sulfuric acid (H_2SO_4) and carbon dioxide (CO_2) by the potash lime.

The space for the subject is large enough for him to stand or lie at ease and move about somewhat. It is furnished with metal chair, table, and bed, all of which may be folded and put away when not in use. An opening in the front, sealed during the experiment, serves as both door and window. In the opposite wall is a smaller aperture, used for passing food, drink, excreta, etc., in or out of the chamber. Tightly fitting caps close each end. There is a telephone for communication with persons outside.

The perfecting of the respiration calorimeter for human experiments opened a new era in nutrition in this country. Calorimeters were built in Washington by the United States Department of Agriculture; at the Pennsylvania State College, by Armsby; in New York, by Lusk, for Cornell University Medical College and the Russell Sage Institute of Pathology; in Boston, by Benedict, for the Carnegie Institution of Washington. These men and their associates have made signal contributions to our knowledge of energy requirements, many of which will be referred to later.

The Modern Portable Respiration Apparatus

The conclusive demonstration, by means of the respiration calorimeter, that energy calculated from the amounts of carbon dioxide excreted and oxygen absorbed by a man lying quietly in the apparatus exactly equals the heat given off by his body in the same period, has made it possible to dispense with the actual measurement of body heat (direct calorimetry) in a great many experiments, and to rely upon studies of the respiration (indirect calorimetry).

The principle upon which Regnault and Reiset built their apparatus in 1850 is that upon which the modern respiration apparatus is constructed. Zuntz, long chief of the Agricultural College in Berlin, made a portable respiration apparatus to measure the energy expenditure of a man walking at sea level or on the snow fields of Monte Rosa, subsequently used with great success by one of his pupils, Magnus-Levy, for the study of respiration in disease. This type of apparatus was brought to a much higher state of perfection in 1918 when F. G. Benedict, director of the Nutrition Laboratory of the Carnegie Institution of Washington, located in Boston, produced his portable respiration apparatus, easy to operate and inexpensive enough to be within the reach of many laboratories. This enables many students with relatively little training in physics and chemistry to have first-hand experience in determining energy expenditures from oxygen consumption and makes concrete to those interested in nutrition as an applied science the accurate scientific foundation upon which the "calorie theory" securely rests.

The Benedict portable respiration apparatus depends upon the principle that the oxygen breathed in by a subject is used in response to a need of the body and is not stored. Consequently, the oxygen consumed is a measure of the amount of combustion going on. As has already been pointed out, the amount of oxygen required to burn a gram of fat is not the same as that needed to burn a gram of carbohydrate or a gram of protein. One hundred grams of

a typical fat (tripalmitin) will yield when burned 141 liters of carbon dioxide and will require from the outside for its combustion 201 liters of oxygen; 100 grams of starch will

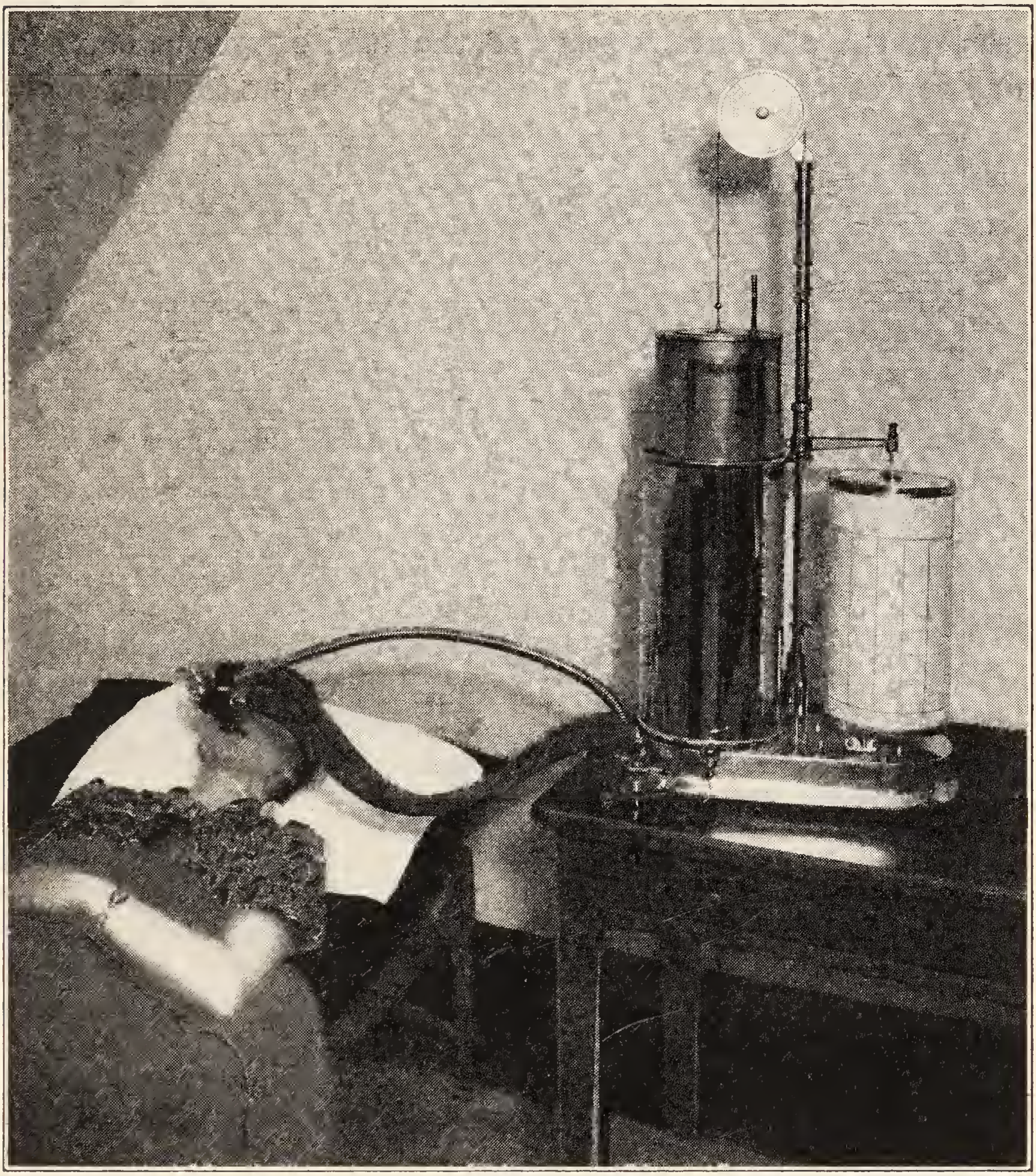


Fig. 8.—Benedict-Roth Portable Respiration Apparatus.
The subject is in position, with mouthpiece inserted and nose clip attached.

yield 83 liters of carbon dioxide and will require 83 liters of oxygen. In other words, the ratio of the carbon dioxide given off to the oxygen consumed in the case of fat is $\frac{141}{201}$ or 0.7, while in the case of starch it is $\frac{83}{83}$ or 1.0. In the case of protein the ratio is about 0.8. These ratios are known as respiratory quotients. If a normal healthy person has gone

from twelve to fifteen hours without food, the carbon dioxide then being excreted represents the burning of the fuel foodstuffs in such proportions as to make a respiratory quotient of 0.82. The subject must always be fasted until all food has left the alimentary tract so that the oxygen consumed may represent the burning of body fuels in the same propor-

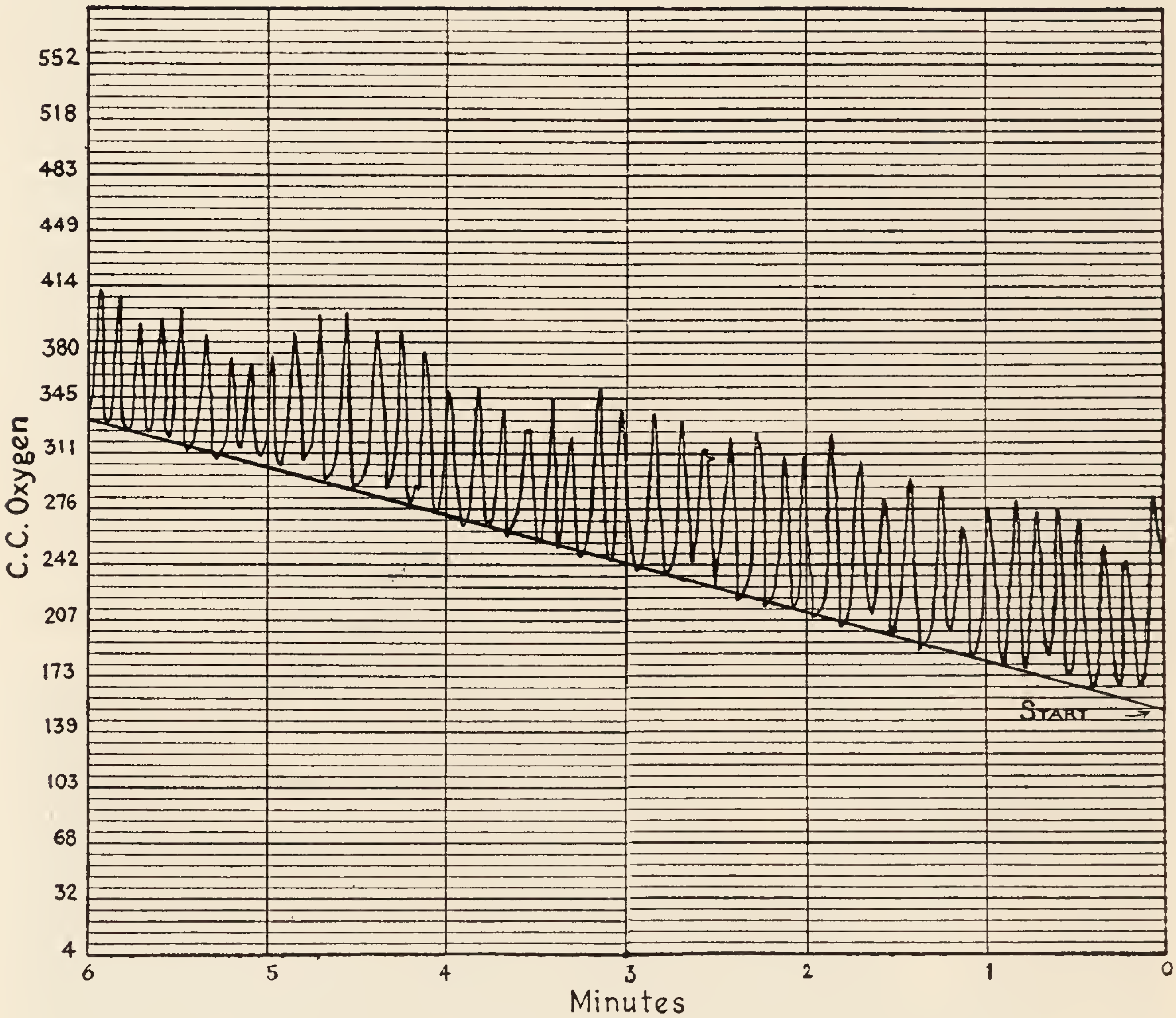


Fig. 9.—Respiration Record in a Basal Metabolism Test.

The tracings mark the rise and fall of the spirometer with each inhalation and exhalation. The difference between the start and the finish gives the volume of oxygen consumed in the time indicated by the vertical lines.

tions in every case. When this preliminary fasting period is not practicable recourse must be had to some type of apparatus in which both oxygen intake and carbon dioxide output can be determined and the respiratory quotient calculated exactly.

In the Benedict portable respiration apparatus the subject is connected with the machine by means of a soft rubber mouthpiece so devised as to prevent escape of air

through the lips, while the circulation of air through the nose is prevented by a spring or a screw clip. The person breathes from a current of air which is kept in circulation by a blower attached to a small electric motor or by a set of valves which allow the current to go only in one direction. The air is constantly purified by the removal of carbon dioxide as it passes

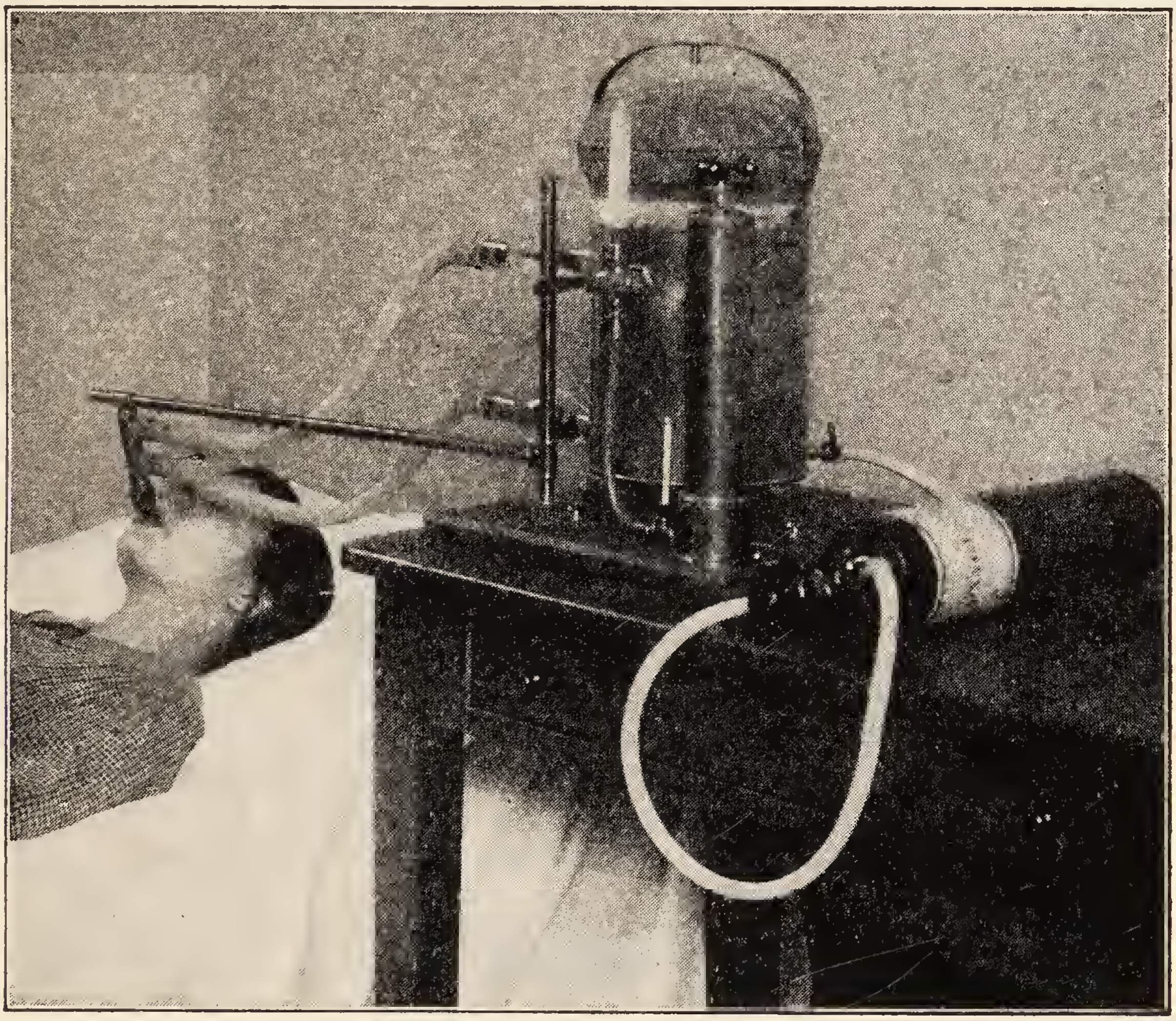


Fig. 10.—The Benedict Student Respiration Apparatus.
Subject is in position and oxygen cylinder is lying on table attached to apparatus.

through a jar of soda lime. It is kept supplied with oxygen by means of a long spirometer into which, before the experimental period, oxygen is run from a storage cylinder. As the oxygen is used up by the subject the spirometer falls. In the type of apparatus shown in Fig. 8, known as the Benedict-Roth, measurement of the oxygen consumed is made by means of a pen attached to the spirometer which writes on a moving drum covered with paper. The drum is driven by a clock and revolves at a constant rate. The paper is ruled vertically so that the time required for the pen to move from one vertical line to the next is one minute.

Horizontal lines correspond to the change in position of the spirometer as the oxygen is consumed, the space between two lines indicating the withdrawal of a definite amount of oxygen. As the spirometer rises and falls, the pen records also the rate and depth of respirations. A line drawn along the points which mark each expiration will give the difference between the first and last readings, as shown in Fig. 9. To

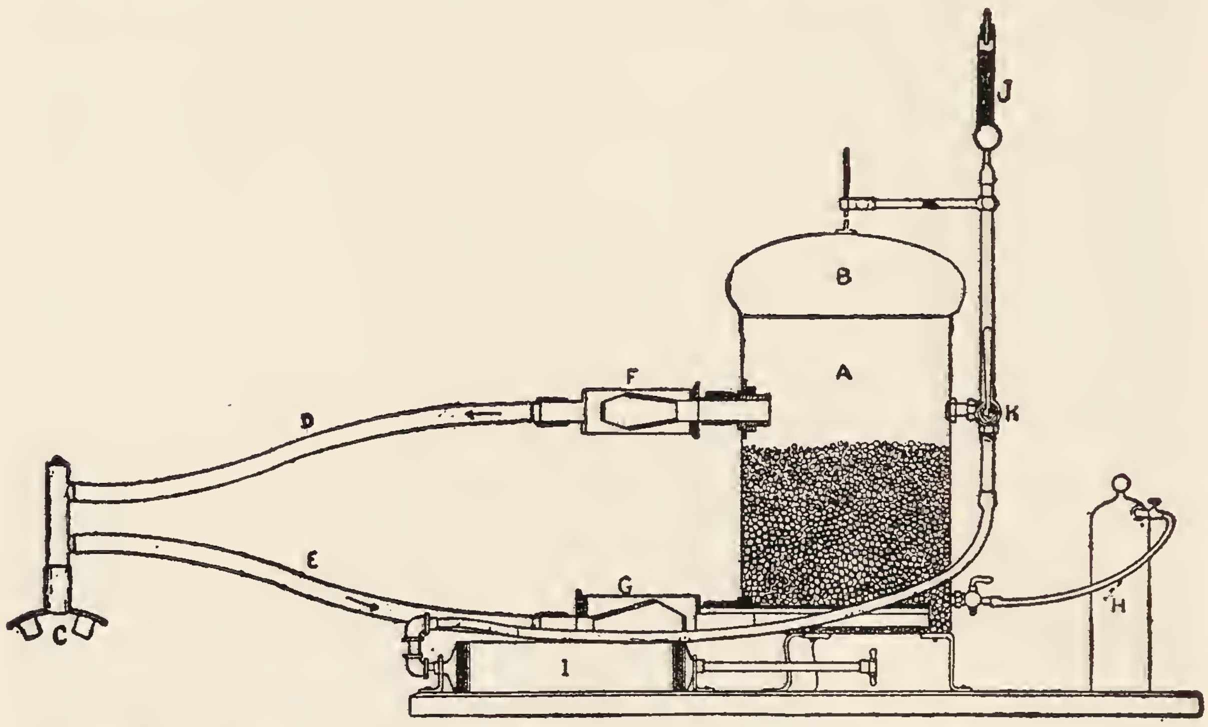


Fig. 11.—Diagram of Benedict's Student Respiration Apparatus.

A. Metal can containing soda lime to absorb carbon dioxide.
B. Bathing cap inflated so that button almost touches marker above it.
C. Rubber mouthpiece.
D and E. Rubber tubes connecting can and mouthpiece.
F and G. Valves controlling direction of air current.
H. Oxygen tank from which a supply of pure oxygen for starting an experiment is introduced into the can.
I. Pump by means of which additional air is supplied to can; it is drawn in through calcium chloride tube, J, which absorbs moisture.
K. Valve through which air from pump is admitted to can.

get the true value of oxygen, corrections must be made for the temperature, the atmospheric pressure, and the moisture in the spirometer.

A more inexpensive type of respiration apparatus, designed by Dr. Benedict for the use of students, is shown in Fig. 10. A rubber bathing cap is substituted for the metal spirometer. This is inflated with oxygen from a cylinder of the compressed gas, until a small button attached to the bathing cap exactly touches a mark on the metal band above it. As the oxygen is consumed by the subject, the button soon fails to

touch the mark, and the oxygen is replaced by pumping in room air, using a small attached automobile grease pump for the purpose. The air pumped in will measure exactly the oxygen removed, since gases at the same temperature and pressure have the same volume. Knowing the capacity of the pump and the number of strokes required to inflate the cap to the mark we can calculate the amount of oxygen consumed in a given time. To find from this the number of calories expended, we apply the well established fact that in combustion in the human body 1 cc. of oxygen consumed will correspond to 0.004825 calorie. For example, a man of average weight, sitting attached to the apparatus for 10 minutes, will consume about 250 cc. of oxygen per minute, and the calories corresponding will be 1.2 calories per minute, or 12 calories in 10 minutes, or 72 calories per hour.

In the hands of experts, results with standard types of respiration apparatus agree closely with those obtained with the respiration calorimeter, and their use in schools and hospitals is eminently practical.

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CHAPTER II

THE BODY'S NEED FOR ENERGY AND FOOD AS THE SOURCE OF SUPPLY

The Body as a Working Machine

From the foregoing historical sketch, we see that animal heat is a sign of combustion (oxidation) going on within the body; and that we can find out just how much food material has to be burned to produce a given amount of heat. But why the burning?

In his attempt to get an exact balance between the carbon dioxide given off by his guinea pig and the ice melted by the guinea pig's body heat, Lavoisier was led to inquire whether or not the body used more oxygen when it was cold than when it was warm; also, whether or not more heat was generated when the animal was quiet than when it was moving about. He extended these inquiries to work on man and found that oxidation was increased by food, by exercise, and by exposure to the influence of cold. "This kind of observation," he wrote, "suggests a comparison of forces concerning which no other report exists. One can learn, for example, how many pounds of weight-lifting correspond to the effort of one who reads aloud, or of a musician who plays a musical instument. . . . What fatality ordains that a poor man, who works with his arms and who is forced to employ for his subsistence all the power given to him by nature, consumes more of himself than does an idler, while the latter has less need of repair?" [1]

One hundred and fifty years of scientific investigation have only served to bring forth more evidence that in regard to its combustion the body must be thought of as a working

[1] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 27. D. Appleton and Co. (1922).

machine. Just as in the engine every revolution of the wheel means so much fuel consumed, so in the body the lifting of the hand, the turning of the head, the bending of the knee, or the "tightening" of all the muscles under excitement means an increase in the combustion going on. But the analogy between the body and the engine breaks down when they come to a standstill. The engine then ceases to work; the body, however, does not, however hard one may try not to move a muscle. The chest and the diaphragm continue to rise and fall with every breath, the heart pumps away, 70 powerful contractions per minute, the muscles though at rest are not by any means fully relaxed; in other words, a great deal of internal work is going on even when one is in a state of apparent repose. The work a man does while sleeping for eight hours may actually equal the more obvious work of his daily vocation, if this be a sedentary one. Measurement of all this work will be considered in detail in a later section. The important point for the moment is that *life means work.* We burn our fuel to support the work which our bodies are doing. It varies in amount with circumstances but it never ceases.

Food as the Source of Energy

When work is to be done, fuel is demanded. This fuel must be supplied as food; in the muscles chiefly it is burned. The chemical union, in muscle cells, of the oxygen breathed in with the carbon (and hydrogen) of the food, is similar to the combustion of gasoline in the automobile engine. The chemical change liberates energy which moves the machine.

The physicist defines energy as power to do work and tells us that it exists as a force in the universe whose sum total cannot be changed. We can alter the form in which it appears and determine the place in which it shall manifest itself, but we cannot add or subract one jot or tittle. He calls this the law of the conservation of energy. The sun is the banker of energy for the earth. Light and heat are the currency. Animals, however, cannot use these forms directly for their

activities. A man cannot make a sun bath take the place of a breakfast. He must get his power to do work from his food. But how does the energy from the sun get into the food? Through the agency of the chlorophyll (green coloring matter) of plants. In the leaf, carbon dioxide from the air, water from the soil, and light from the sun can be bound together, making chemical compounds full of stored (potential) energy.

Let us take the corn plant as an example. Roots, stem, and leaves are chiefly woody fiber and water. The fiber will burn in a stove, yielding its stored energy as heat and light. The stem and the leaves can be eaten by cattle and, through long chewing and slow digestion, the stored energy of the plant fiber, or cellulose, may be released for the animals' benefit. A man, however, has no mechanism by which any considerable part of the energy of this fiber can be set free within his body; for him, it is not fuel. The seed, or kernel, is packed with starch grains. These will give heat when burned, but are too precious to use in a stove, for they will serve as fuel for men and animals. Furthermore, from the germ of the seed we can extract a fat, corn oil, which, too, would burn in a stove or a lamp, but is more useful as body fuel. Finally, from this same seed we can get another substance known as corn gluten, like the oil and starch inflammable in the ordinary sense and also combustible in the body.

From this one plant, then, we can obtain three kinds of material which will serve as sources of energy for the human machine. "It may be estimated that a 50 bushel corn crop would contain in grain and fodder nearly 10,000 therms (10,000,000 calories) of energy per acre, sufficient, if it were all converted into heat, to raise the temperature of 100 tons of water from the freezing point to the boiling point." [1] These materials burn because they all contain a considerable amount of carbon and some hydrogen, both of which are capable of uniting with oxygen. Chemically, starch is closely

[1] Armsby, Henry P. *Conservation of Food Energy*, page 12. W. B. Saunders Co. (1918).

related to sugar, which is also available as fuel in the body. These both belong to a group of chemical substances called carbohydrates. Corn gluten belongs to another chemical group known as proteins. Carbohydrates and fats are alike in that they each yield but three chemical elements: carbon (C), hydrogen (H), and oxygen (O). The proteins yield these three, and in addition nitrogen (N) and usually one or more of the following: sulfur (S), phosphorus (P), iron (Fe). These last four have nothing directly to do with the use of protein as fuel, however. All the food fuels burn because of their carbon and hydrogen and all yield carbon dioxide and water when oxidized. We may think of the situation thus:

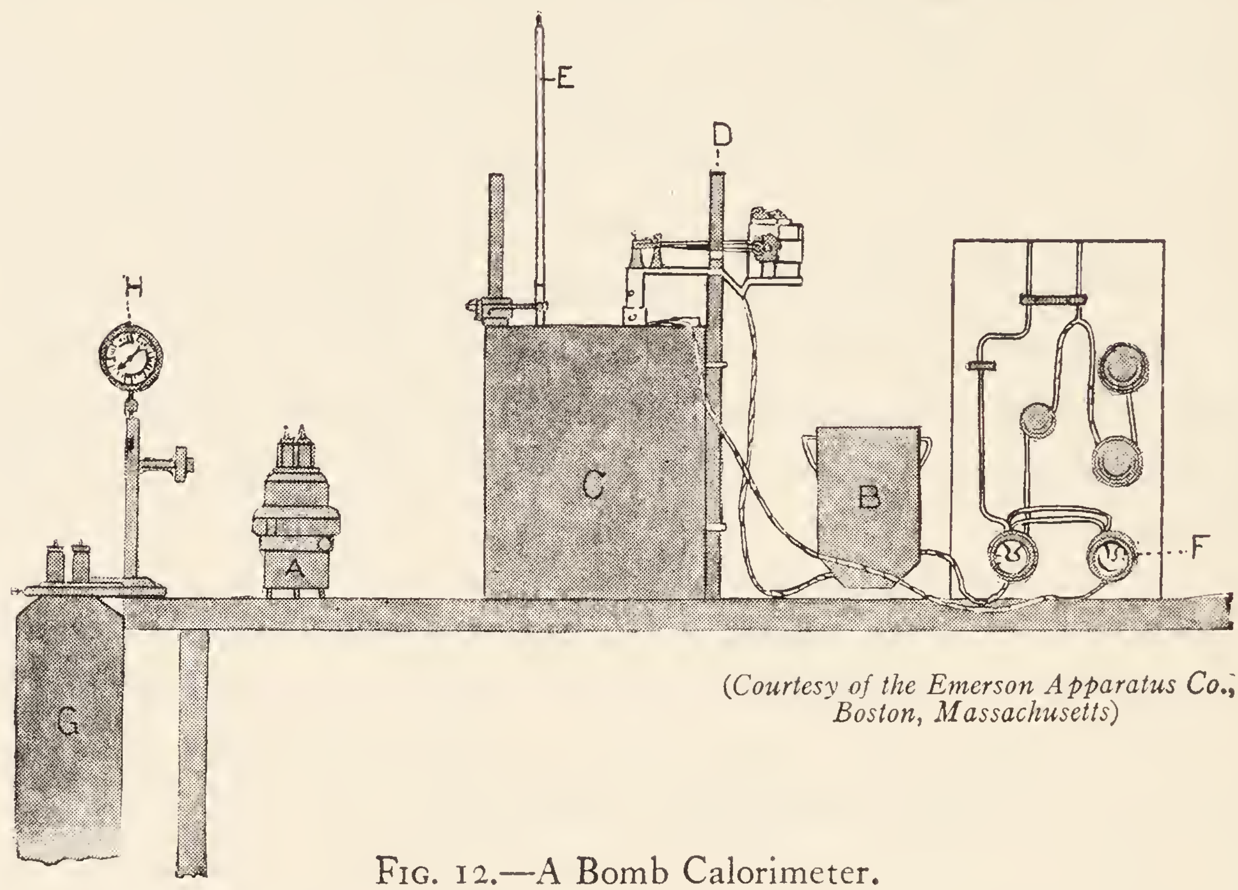
$$\begin{array}{c} \text{Energy of} \\ \text{sun's rays} \end{array} + \begin{array}{c} \text{Chlorophyll} \\ \text{of plants} \end{array} + \begin{array}{c} \text{Carbon dioxide} \\ \text{of air} \end{array} + \begin{array}{c} \text{Water} \\ \text{from} \\ \text{soil} \end{array} =$$

$$\text{Energy yielding materials} \left\{ \begin{array}{l} \text{Carbohydrates} \\ \text{Fats} \\ \text{Proteins} \end{array} \right.$$

Just as the plant stores up in the form of these three chemical groups, carbohydrates, fats, and proteins, the energy derived from the sun—now in roots, as the beet; now in thickened stems (tubers), as the potato; now in fruits, as the orange—so animals, eating these fuel foods in excess of their immediate needs, may store the surplus energy in their own bodies against a time of future need. Here is another point where the analogy between the body and the engine breaks down. If you pile coal upon the fire and generate more than enough steam you have to let the surplus escape; it cannot be saved for next month or next year; but if the body has a surplus of fuel it can be converted into body fat (chiefly) and stored away until actually needed. According to Armsby, a thousand pound steer given 14 pounds of timothy hay daily will just about support himself without gain or loss. If we want him to store up food for man we must increase his fuel supply and thus give him a surplus to store.

The Measurement of Energy in Food Materials

We have recalled the fact that energy is a force which manifests itself in various forms: now as work, lifting a weight



(*Courtesy of the Emerson Apparatus Co., Boston, Massachusetts*)

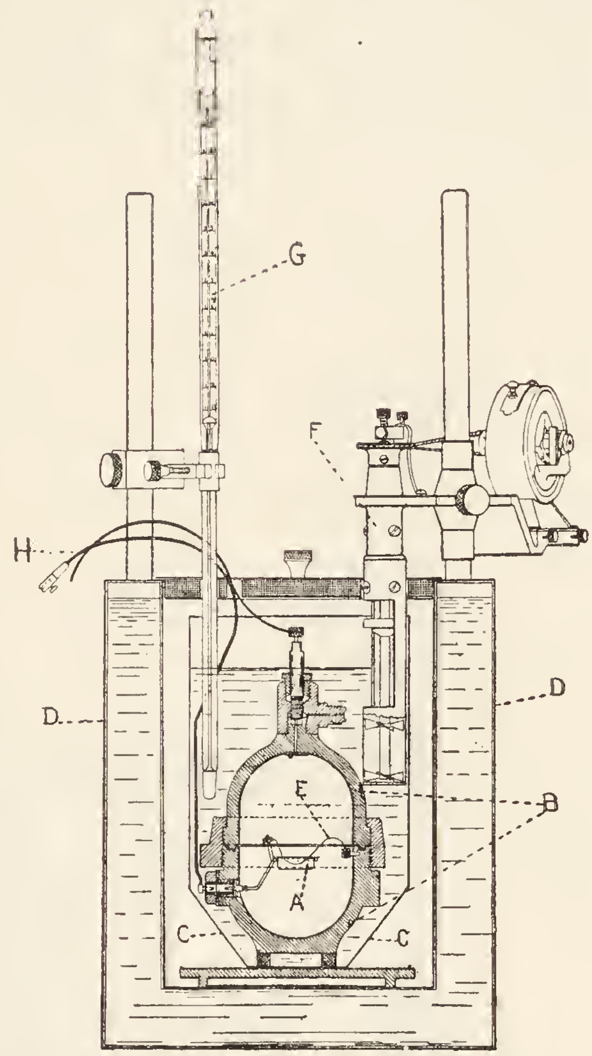
Fig. 12.—A Bomb Calorimeter.

A. Steel bomb holding sample.
B. Can containing water in which bomb (A) is placed.
C. Double-walled container in which can (B) is placed.
D. Motor-driven stirrer to agitate water.
E. Thermometer to note temperature changes in water.
F. Electrical connection for wires to bomb to ignite fuse and to stirrer.
G. Oxygen tank.
H. Pressure gauge to measure oxygen introduced into bomb.

or pulling a load; now as heat, liberated from burning coals in the furnace; now as light, from the burning tallow of the candle; now as electricity, from the stored force of the river raging over the precipice; now as the invisible force which spans the space between chemical atoms in a molecule, and reveals itself only when they rush together in combustion, with an impact violent enough to produce vibrations which we sense as heat or light. This force can be measured in various ways: the light in terms of candle power; the heat in calories; the electricity in kilowatt hours; the work as foot-pounds or kilogrammeters. Which shall we choose as our basis for the study of foods?

Since the energy of foods is to be compared with the work

which the body must do, a work unit would seem most practical. Then we might use as our starting point the amount of energy required to lift one pound of material one foot into the air. In the laboratory, however, it is much easier to convert all the potential energy of a food material into heat, and having done so, it is simpler to use a heat unit directly than to recalculate each time to a work unit. Furthermore, in the resting body all the energy of internal work eventuates as heat, and whenever external work is done, heat is a by-product of the activity. Hence it is customary, although the energy of food is not used directly as heat, to measure it by a heat unit for convenience's sake. This unit is called the calorie and it has long been in use in physical laboratories for all sorts of energy measurements. [1]



(*Courtesy of the Emerson Apparatus Co., Boston, Massachusetts*)

FIG. 13.—Diagram of Bomb Calorimeter with Bomb in Position.

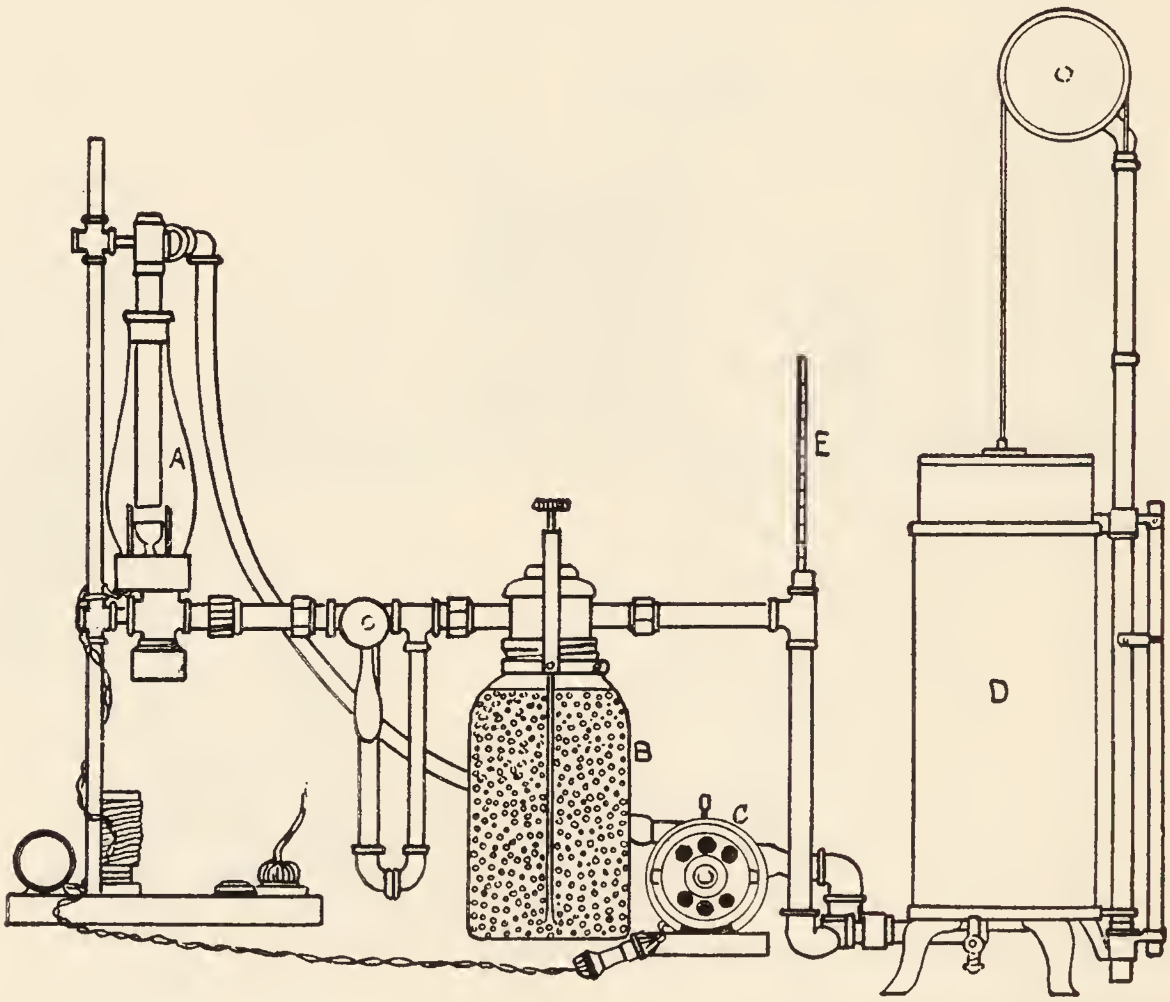
A. Platinum dish holding food sample.
B. Bomb filled with pure oxygen enclosing food sample.
C. Can holding water, in which bomb is submerged.
D. Outer double-walled insulating jacket.
E. Fuse, which is ignited by an electric current.
F. Motor-driven water stirrer.
G. Thermometer.
H. Electric wires to send current through fuse.

The Bomb Calorimeter

We cannot see a calorie any more than we see the feet of gas which the meter registers or the kilowatts for which we pay when the monthly electricity bill comes in. We are bound to depend upon the meters for those measurements and, similarly, we must depend upon a special device in determining the energy values of foods. The apparatus most

[1] The large calorie is taken as the standard for the science of nutrition.

commonly used is called a bomb calorimeter. It consists of an inner chamber or "bomb" made of steel and lined with gold or platinum so as to be noncorrosive, into which the material to be tested is put. This chamber is filled with pure oxygen, so that combustion may be quick and complete when a tiny "fuse" of iron wire is ignited by an electric



(*Courtesy of Dr. F. G. Benedict*)

FIG. 14.—The Benedict Oxy-Calorimeter.

A. Combustion chamber.
B. Vessel containing soda lime to absorb carbon dioxide.
C. Blower to circulate air current.
D. Chamber (spirometer) to measure by contraction the volume of oxygen used.
E. Thermometer.

spark. The bomb is immersed in a known amount of water, and the heat generated by the burning of the food is measured by observing the change in temperature of the water.

This apparatus is used very widely to determine the energy values of fuels, such as coal and oil, as well as for foods. While simple in principle it requires skill to operate, because the chances of losing heat and not getting a correct measure are great.

The Oxy-Calorimeter

Another apparatus devised for the same purpose is the Benedict oxy-calorimeter. This was devised by Dr. and Mrs. Benedict to use especially for foods, and has proved a great convenience in nutrition laboratories. The food under consideration is burned in a current of nearly pure oxygen, and the volume of oxygen consumed in its complete combustion is measured in much the same way as in the Benedict student apparatus as described in Chapter I. Oxygen is introduced into a closed circuit, changes in volume are indicated by a spirometer, circulation is maintained by a blower, and carbon dioxide is absorbed by soda lime. The various parts are indicated in Fig. 14. Standard factors for converting liters of oxygen into calories have been obtained by use of the bomb calorimeter. For example, in burning pure sugar, if the oxygen consumption amounts to 1,000 cc., this will represent energy equivalent to 5 calories. For each kind of food the number of calories represented by an oxygen consumption of 1,000 cc. have been determined once for all, and can be applied to any quantity of the food which the apparatus can take care of.[1]

Calculation of Energy Value of Food

Since foods contain sometimes one kind of fuel only, as common sugar; sometimes two, as eggs; sometimes all three, as milk; and since these will be in different combinations and different proportions, according to the food under consideration, it saves labor to have the laboratory investigator tell us how many calories there are in a given weight of protein, fat, and carbohydrate, respectively, and then to make a few calculations ourselves, using tables of chemical composition for this purpose.[2] The physical laboratory gives us the following average values:

1 gram of pure carbohydrate, 4.1 calories
1 gram of pure fat, 9.45 calories
1 gram of pure protein, 5.65 calories

[1] For such factors as have been determined see Benedict, F. G., and Fox, E. L. *The Oxy-Calorimeter. Industrial and Engineering Chemistry*, Vol. 17, page 912 (1925).

[2] A comprehension table giving protein, fat, and carbohydrate content of food materials will be found in Rose's *Laboratory Handbook for Dietetics*, 4th edition (1937), Table XIX.

The physiological laboratory tells us that we must make certain deductions from these values because protein is never quite completely burned in the body and there is every reason to expect in case of all three foodstuffs slight losses due to incomplete absorption from the alimentary tract. The discounts proposed for an ordinary mixed diet by Atwater and Bryant after much careful study of the situation are: for carbohydrate, 2 per cent; for fat, 5 per cent; for protein, 29.2 per cent. Thus we get as final figures to use in our estimates of the fuel values of food to the body:

1 gram of pure carbohydrate, 4 calories
1 gram of pure fat, 9 calories
1 gram of pure protein, 4 calories

If we take as an example cane sugar, our problem will be very simple, since cane sugar is 100 per cent carbohydrate, and each gram will yield 4 calories; if we take olive oil, which is pure fat, each gram will yield 9 calories; and if we take dry gelatin, which is pure protein, each gram will yield 4 calories. But if we undertake to determine in this way the fuel value of milk we shall find the situation a little more complicated, for milk contains all three:

Calculation of Energy Value of One Gram of Milk

	Amount in Grams	Factor	Calories
Protein	0.033	4	0.132
Fat	0.040	9	0.360
Carbohydrate	0.050	4	0.200
			0.692

It is evident that the above calculations can be made once for all and recorded for future reference, thus saving much unnecessary labor.

Standardizing Energy Values of Foods for Practical Purposes

It is worth while to spend the time necessary to learn the energy values of ordinary food materials, just as it is worth while to learn the multiplication table or the order of the

letters of the alphabet. One may begin with various common units in the diet, as shown in the following table:

ENERGY VALUES OF COMMON FOOD UNITS

FOOD MATERIAL	ENERGY VALUE IN CALORIES	
	Range	*Medium*
1 almond	6–10	8
1 apple	60–100	80
1 banana	80–120	100
1 beet	15–50	30
1 caramel	45–55	50
1 egg	65–100	75
1 onion	20–100	30
1 orange	60–100	80
1 oyster cracker	4–6	5
1 potato	90–150	100
1 shredded wheat biscuit	95–110	100
1 tomato	25–50	40

One may profitably extend such tables to include one's own customary portions of all sorts of dishes, but as individuals differ very much in regard to their habits of eating, it is not possible to make standard tables on the basis of "servings," although one may find interesting and useful tables based on the judgment of certain individuals or groups as to what constitutes a "serving." [1]

For systematic and comprehensive study of foods it is more satisfactory to adopt a standard energy unit, and the 100 calorie portion originally suggested by Irving Fisher, Professor of Economics in Yale University, has proven eminently practical. In the Appendix will be found a table giving the weights of 100 calorie portions of many common food materials. With the assistance of these, and accurate scales, one may readily become familiar with the quantity of any single food material required to yield 100 calories by simply consulting the table and weighing out the quantity indicated.

When it comes to cooked foods the matter is not quite so simple. A standard table gives the weight of 100 calories of

[1] A comprehensive table of calories in common measures of food will be found in Table I of the Appendix.

dry rolled oats as 25 grams.[1] In cooking, water is added, more when the mush is thin and less when it is thick. The weight and measure of the cooked product will vary accordingly. By having a large number of persons trained in cookery prepare a 100 calorie portion to the best of their ability and taking the average, one arrives at fairly representative figures for both weight and measure of cooked rolled oats: measure, ¾ cup; weight, 4.8 ounces.

The chances of variability in a portion of a food simply cooked with water, like oatmeal, are less than they are in the case of food mixtures for which there may be several recipes. This is illustrated very well by so simple a food mixture as cocoa, in which the amount of sugar and milk and the presence or absence of cream are the commonest variables. A cup of cocoa made with half milk and half water will yield only 145 calories, while if made with milk exclusively, it will yield 85 more. If 2 tablespoons of cream are added, the energy value will be more than double that of the first cup, as shown in the following table:

Energy Value of Cocoa Prepared in Different Ways

Cocoa I	Cocoa II	Cocoa III	Cocoa IV
Milk, ½ cup Water, ½ cup Cocoa, 2 tsp.[a] Sugar, 2 tsp.	Milk, 1 cup Cocoa, 2 tsp. Sugar, 2 tsp.	Milk, ½ cup Water, ½ cup Cocoa, 2 tsp. Sugar, 3 tsp. Cream, 1 tbsp.[b]	Milk, 1 cup Cocoa, 2 tsp. Sugar, 3 tsp. Cream, 2 tbsp.
Calories in recipe 145	230	232	370
100 calorie portion 7 tbsp.	5 tbsp.	5 tbsp.	3¼ tbsp.

[a] tsp. stands for teaspoon.
[b] tbsp. stands for tablespoon.

From the foregoing examples it is obvious that tables of 100 calorie portions of cooked food materials must be accepted with caution when not accompanied by recipes.[2]

[1] 1 ounce = 28.35 grams.
[2] For food values of recipes see Rose's *Feeding the Family*, 3rd edition, pages 349–431, The Macmillan Co. (1929), and Rose and Taylor's *Food Values of Recipes in Shares*, 2nd edition, Bureau of Publications, Teachers College, Columbia University (1936).

With suitable tables at hand, it is possible to estimate with considerable accuracy the energy yield of a day's ration, as the following illustration will show:

CALORIES IN A DAY'S DIETARY ESTIMATED BY MEASURE FROM 100 CALORIE PORTIONS

Food Materials in a Day's Dietary	Measure of 100 Calorie Portion	Amount Eaten Measure	Calories Consumed
Apple, baked	½ large apple	1 apple	200
Beef, roast	1 slice 5″x2½″x¼″	1½ slices	150
Bread, white	2 slices 3″x3½″x½″	6 slices	300
Butter	1 tablespoon	6 tablespoons	600
Cream, thin	¼ cup	¼ cup	100
Cream, whipped	2 tablespoons	2 tablespoons	100
Eggs	1⅓ egg	1 egg	75
Lemon jelly	½ cup	½ cup	100
Milk	⅝ cup	2 cups	320
Oatmeal	¾ cup	¾ cup	100
Peas, creamed	½ cup	¾ cup	150
Potato, baked	1 medium	1 large	150
Prunes	4 medium	4 medium	100
Roll	1 roll	1 roll	100
Sugar	2 tablespoons	2 tablespoons	100
Total			2,645

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[1] Consult also the references for Chapter VI.

CHAPTER III

THE ENERGY REQUIREMENT OF ADULTS

In the foregoing chapter we have seen that the dream of Lavoisier has come true. We have arrived at the point where we can measure, with greater precision than the pharmacist who weighs out powerful drugs on the most delicate apothecary's scales, the amount of oxidation which is going on in the animal body under any given set of conditions. Not only because of its historical interest is it fitting to begin our study of nutrition with the energy exchange, but also because, quantitatively speaking, the greatest demand which we make upon food is that it shall supply us with calories. There are other food factors equally important qualitatively to be discussed in their turn, but in ordinary daily life few of these can be secured independently of the energy supply, while all of them may and most of them must be obtained incidentally to it.

Practically, our task is to learn first how many calories we need and then to see how, by intelligent choice of foods which yield them, we may make them the carriers of every other dietary essential. This will eventually involve much study of individual foods, for, in the words of Armsby, long the distinguished director of the nutrition research laboratory at Pennsylvania State College, the problem of rationing a people "is very far from being so simple a thing as merely supplying a certain number of calories of energy or grams of protein. Questions of palatability, of dietary habits, of market facilities, and of costs of fuel, labor, transportation, and marketing both in agricultural and manufacturing industries, all these have to be considered." [1] But we shall pursue our study of these far more successfully if we have as a foundation

[1] Armsby, H. P. *Conservation of Food Energy*, page 13. W. B. Saunders Co. (1918).

a clear conception of energy requirements and how they may be met. In approaching the study of the energy requirement of adults, we have to bear in mind the fact that energy expenditure varies greatly with conditions of existence: it rises rapidly, for instance, when a man who has been sitting in a railroad station and has fallen asleep while waiting for his train wakens to find it pulling out, and bolts through the doorway on a dead run to catch it; it falls when an athlete who has been doing a hundred yard dash crosses the line and sinks down to rest after his sprint.

But it is always well to remember, as aptly stated at the White House Conference on Child Health and Protection in 1932, that "nobody has yet found a way to increase energy economy, muscular efficiency, for example, by addition of vitamins and salts, in short, by substituting quality for quantity. Muscular effort is being reduced in all departments of modern life; we require fewer calories as we become more 'civilized,' but the physiological cost per foot-pound of work performed by the body is affected only by extraneous factors like heated work shops, convenient benches, competition, perhaps, and acquired skills . . . the fundamental cost remaining unchanged." [1]

In order to systematize the factors causing such variability, we shall take as our starting point a state of energy expenditure which is practically constant from hour to hour for a given individual and is known as the basal metabolism.

Section I

THE BASAL METABOLISM

The term metabolism is used broadly for all the chemical changes which take place within the body under the influence of living cells. Some of these changes are concerned with the construction of body substance from materials taken from the environment as food; some with the maintenance of es-

[1] *White House Conference on Child Health and Protection.* "Growth and Development of the Child," Part III, "Nutrition," page 334. The Century Co. (1932).

sentially stable tissues in an organism in which flux is the law of life; and some, as we have already seen, with the use by the body of energy-yielding materials for its internal and external activities. It is with the last of these that we are now concerned, and the general term energy metabolism is employed to designate those chemical processes which have to do with the combustion of fuel to run the human machine.

If we measure the energy expenditure of an adult each morning after he awakens but before he rises from his bed and begins to take food or to dress, we shall find in the course of a week a striking similarity in the daily returns, and we may be surprised at the amount of "internal work" which is going on. In warm blooded animals, as Regnault observed in his pioneer investigations, the resting energy expenditure is always higher than in cold blooded ones. The warm blooded animal seems to live on a spendthrift plane so far as energy is concerned. This is correlated with the fact that he depends upon the heat which is a result of his internal activities for the maintenance of a uniform temperature for the body cells, despite fluctuations in the temperature of the environment. There is an irreducible minimum of energy expenditure, without which life is impossible. The absolute minimum is not reached in the waking but in the sleeping state; it is, however, more practical to take as the line of reference the energy output of the subject awake, lying quiet and comfortably relaxed, twelve to fourteen hours after the last meal. This is called the basal metabolism.

The Basal Metabolism of the Adult

The basal metabolism of a young man of average weight (154 pounds or 70 kilograms) is about 1,700 calories for the twenty-four hour day; that of an average woman of similar age, about 1,300 calories. If we put this in terms of a few common food materials, we shall perhaps realize its significance a little better.

Food Yielding Calories to Equal an Average Man's Basal Metabolism for One Day

Food	Calories
Apple, 1 medium	80
Bread, $5\frac{1}{2}$ ounces	400
Butter, 4 tablespoons	400
Lamb chop, 1 lean	200
Milk, 1 pint	340
Orange, 1 medium	80
Potato, 1 medium	100
Shredded wheat, 1 biscuit	100
Total	1,700

Cutting out three fourths of the bread and one fourth of the butter reduces this to the amount equivalent to the daily charge on existence for the so called average woman (weighing 123 pounds or 56 kilograms).

To be strictly accurate, the intake and the outgo of energy will not quite balance with the eating of this food, because food itself has a stimulating effect which will raise the energy expenditure about 6 per cent; hence, to avoid drawing at all upon body reserves it will be necessary to add about one hundred calories to the basal metabolism. This will be discussed further in the next section.

Basal Metabolism in Terms of Body Weight and Body Surface

It is often most convenient to think of the basal metabolism in terms of body weight. If Mr. Jones and Mr. Brown are both the same age, but one weighs 150 pounds (68.2 kilograms) and the other 180 pounds (82 kilograms), the total basal metabolism of the one will be about 1,637 calories and of the other about 1,968 calories. These figures do not tell us that the basal metabolism of these men is really the same, but if we divide total calories by body weight we get the same figure, 24 calories per kilogram per day.

For the young adult of average size it has been found that the basal metabolism lies very close to one calorie per kilogram per hour. At this rate, the man of average weight (70 kilograms) would have for 24 hours a basal metabolism of 1,680 calories ($1 \times 70 \times 24$).

Scientifically, a more accurate prediction of the basal metabolism can be made on the basis of the surface area of the body. This we cannot measure for ourselves, but DuBois has given us tables for determining body surface when weight and height are known.[1] These tables are derived from actual measurement of the body surface of a number of persons. The subject to be studied was dressed in close fitting underwear, thin socks and gloves, and a section of the leg of a knitted garment made a covering for head and neck. Upon this foundation strips of manila paper were pasted to make a complete mold of the body. This mold was carefully removed in sections, then these were cut into pieces small enough to lie flat, and photographed on weighed paper. The imprints were cut out and weighed, and their weight compared with that of the whole sheet of paper whose area was known, thus making it easy to determine the surface area of the entire body or of any desired portion.

A normal man, weighing 70 kilograms and standing 5 feet, 8 inches high, or 173 centimeters, will have, according to the DuBois tables, a body surface of 1.83 square meters, and, if under 40 years of age, his basal metabolism will be very close to 39.5 calories per square meter per hour. His total basal metabolism for 24 hours will then amount to 1,735 calories (39.5 × 1.83 × 24). A woman under 40, weighing 56 kilograms and 5 feet, 4 inches tall, or 163 centimeters, will have a body surface of 1.60 square meters and a basal metabolism of 34.2 calories per square meter per hour, making a calculated total of 1,313 calories per day. These figures may be summarized as follows:

Average Basal Metabolism of a Man and Woman under 40 Years of Age [2]

	Weight Kg.	Surface Area Sq. M.	Calories per Sq. M. per Hr.	Calories per 24 Hrs.
Male	70	1.83	39.5	1,735
Female	56	1.60	34.2	1,313

[1] A chart for this purpose will be found on the last page of the Appendix.

[2] For other ages see pages 58 and 67.

Boothby and Sandiford of the Mayo Clinic, Rochester, Minnesota, have published data on 102 normal persons between the ages of 21 and 69 years and compared their basal metabolism as actually determined with that calculated in the above fashion. They found that in over half the cases the predicted value did not fall more than 5 per cent above or below the actual value, and in only 7 cases was the deviation more than 10 per cent in either direction. Some of the reasons for these divergences from the average rate of metabolism will be discussed in the next chapter.

Section 2

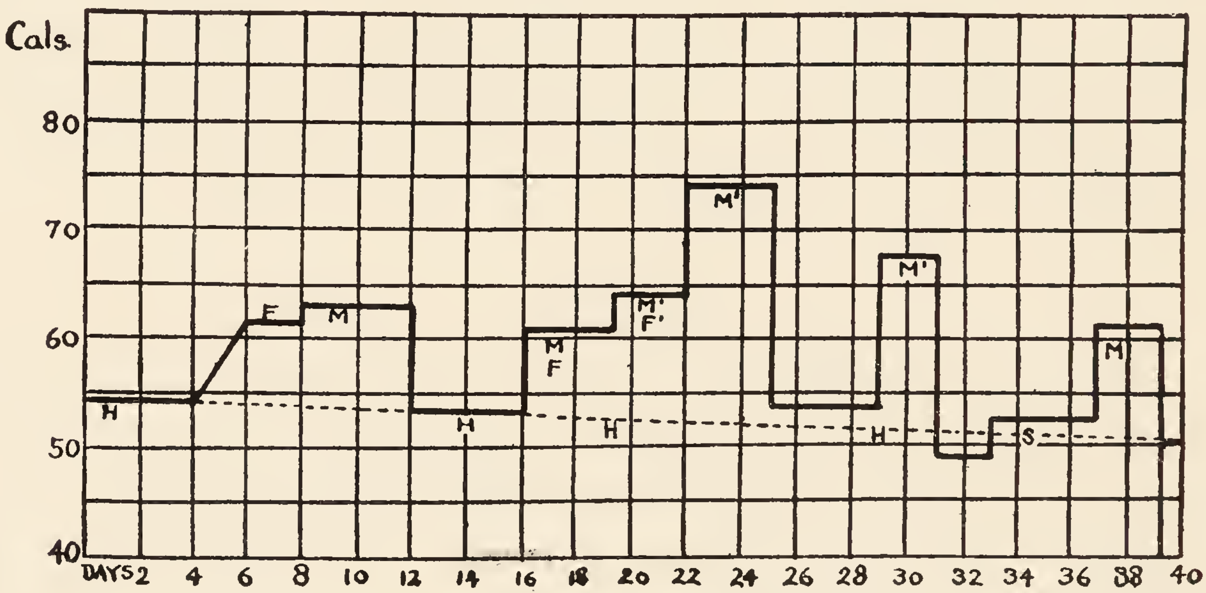
THE ALLOWANCE FOR THE INFLUENCE OF FOOD

While the basal metabolism constitutes an important and strikingly constant quota of the energy expenditure, no one could live long on the basal level. No one could remain absolutely quiet all the time, no one could subsist without food, which itself increases the energy output. In ordinary daily life, what allowances must be made for the taking of food and for the muscular movements which are an inevitable part of existence?

Lavoisier was the first to note that eating food increased the amount of oxygen absorbed by his subject, Seguin. Sixty years later, Bidder and Schmidt gave a starving cat all the meat it would eat and found that the oxygen absorption and carbon dioxide output were doubled in consequence. Ten years after this (1862), Pettenkofer and Voit fed a dog different quantities of meat and found that the larger the meat meal the greater the combustion within the organism. They then tried fat and starch and found that the increase with fat was smaller than with starch, and neither had any such marked effect as meat. Rubner carried this investigation much farther and learned that bones, water, and meat extracts had no effect. Hence he called this stimulating effect of food, which he found to be of a different order of magnitude for protein, fat, and carbohydrate, "specific dynamic action."

His chart recording the results of some of these experiments is very interesting (Fig. 15).

That man responds in a similar fashion, Rubner showed in another experiment, in which a man was given a calorie allowance 20 per cent above his energy expenditure without food, first of sugar and then of meat. The sugar alone raised



(Archiv für Hygiene, *Vol. 46, page 390, 1903*)

Fig. 15.—Rubner's Experiment Showing Changes in Energy Expenditure Due to Changes in the Kind of Food, Expressed in Calories per Kilogram of Body Weight.

H. Fasting metabolism.
F. Fat exclusively.
M. Meat 66% of total calories.
MF. Meat 10%, fat 90% of total calories.
M'F'. Meat 20%, fat 80% of total calories.
M'. Meat exclusively.
S. Sugar 87% of total calories.

the output 2.2 per cent in twenty-four hours, while the meat alone raised it more than 25 per cent, or ten times as much. If the food fed is practically all carbohydrate the rise of metabolism following its ingestion will be about 6 per cent of the total; i. e., for every 100 calories an extra 6 must be allowed for the whipping up of cell activity as this food is absorbed from the intestinal tract and begins to circulate in the blood stream. The effect of fat is about the same, 6 to 14 per cent, but that of protein is very marked, amounting to at least 30 per cent.

We are most interested in the effect of a mixed diet, because we do not usually eat a single kind of fuel food by it-

self. DuBois has summarized the work of investigations made in the Nutrition Laboratory of the Carnegie Institution of Washington, Boston, and in the Russell Sage Institute of Pathology, New York City. A very small breakfast (222 calories for men weighing 65 and 74 kilograms, respectively) increased the heat production 5.4 calories, or a little over 2 per cent of the total calories. A heavy breakfast (over 2,142 calories) is estimated to have increased it 111 calories (5.2 per cent), while a very heavy breakfast (3,936 calories) gave an increase of 290 calories (7.4 per cent).

DuBois concludes that it would seem safe to add an amount which equals from 5 to 6 per cent of the calories of the food where the person is on a maintenance ration (i. e., one just covering energy requirement at rest). On an ordinary mixed diet, meeting requirement for activity in addition to maintenance requirement, we also allow about 6 per cent of the total intake for the influence of food. This is assuming that such a diet does not consist largely of protein rich foods.

The effect of a beefsteak by itself is strikingly shown in an experiment by Benedict and Carpenter, where approximately 9 ounces (418 calories) were eaten, with the result that the heat production was raised 138 calories, or one third of the total energy value of the steak. These calories were lost as heat and were not available for any useful work in the body. DuBois aptly remarks: "In this manner some of the excess food is burned and wasted just as a surtax diminishes a large income."

There is one circumstance in which the "tax" may be returned to the citizen's own pocket, so to speak. On exposure to cold, there is, as we have already seen, a tendency for the metabolism to rise for the primary purpose of maintaining the normal body temperature. Now if meat be fed, the heat which is evolved during the transport to the body cells of the amino acids set free in the process of digestion of the protein can be turned to account instead of being wasted. This is quite clearly shown by a series of experi-

ments conducted by Lusk on a dog. The basal metabolism was determined at various temperatures from 7° C. (44.6° F.) to 30° C. (86.0° F.). At ordinary room temperature it was about 56 calories per kilogram; at 7° C. it was over 50 per cent higher. At ordinary room temperature, giving the dog 11 ounces of meat raised his metabolism from 56 to 76 calories, a waste of 36 per cent. When the temperature fell to 7° C., the basal metabolism rose to 86 calories per kilogram. Upon being given meat in the same amount as before, there was practically no increase in the heat production. The 20 calories which were dead loss in the first instance, when no extra heat was needed, were turned to good account in the second case, in which heat equivalent to 30 extra calories was required.

Section 3

ALLOWANCES FOR THE INFLUENCE OF MUSCULAR ACTIVITY

A person having his basal metabolism determined finds the necessary ten minutes a long time to keep still. Ordinarily, lying still in bed means turning over now and then, bending and unbending the legs, shifting arms and hands; such "activity" may easily add 10 per cent to the basal metabolism. When a person sits absolutely quietly in a chair, the metabolism will average 8 per cent higher than when lying down. Not long, however, will any one sit perfectly still. If one watch his neighbors "sitting still" for a short time, listening to an address in church or in the classroom, he will find few who do not make a good many minor motions, as the following random studies show:

Movements of Adults "Sitting Still"

Person	Time	Hands to Face	Readjusting Position	Moving Hands	Moving Feet	Moving Head	Total
Woman	25 min.	0	3	6	9	28	46
Woman	25 min.	16	5	27	2	17	67
Man	25 min.	8	4	26	1	10	49
Man	25 min.	2	1	3	0	5	11

To estimate the energy expenditure involved in "sitting still," therefore, we proceed as follows:

	Calories per Kg. per Hr.
Basal metabolism	1.00
Muscular work—holding head and trunk in sitting posture	0.08
Slight muscular movements	0.20
Total	1.28

To this amount we must, under ordinary living conditions, add the influence of food; allowing 6 per cent of the basal metabolism plus the requirement for muscular work, we have a total of 1.36 calories per kilogram per hour.

Again, if one stand upright, taking an easy pose, the energy expenditure will be raised by the muscular effort of holding the entire body erect about 20 per cent above the sitting level, or 28 per cent above the basal metabolism; if more tension be put into the muscles, as in standing "at attention," the energy output goes up still more, registering an increase of over 50 per cent above the basal metabolism.

	Calories per Kg. per Hr.
Basal metabolism	1.00
Muscular work—standing "at attention"	0.60
	1.60
Influence of food (6 per cent of total)	0.10
Total	1.70

As soon as one begins to move about, as in walking even at a very slow pace, the expenditure becomes double that of "sitting at rest," and if one walk rapidly it may rise to four, five, or six times the sitting value.

Benedict and Parmenter, experimenting with 12 young women at Mount Holyoke College, South Hadley, Massachusetts, found the energy expended in stair-climbing to be about 15 times that required for walking the same distance on the level at the rate of about 2 or 2½ miles per hour. These young women climbed a mountain stairway of 522 steps up the side of Mount Holyoke at a rate of about 80 steps a minute attached to a very simple type of respiration ap-

paratus, so arranged that the weight of everything except the mouthpiece was supported by an operator who walked

(Courtesy of Dr. VeNona W. Swartz and the Director of the Agricultural Experiment Station, Pullman, Washington)

Fig. 16.—The Benedict Knapsack Apparatus Being Used to Study the Energy Cost of Paring Potatoes.

Attached to the mouthpiece are two one-way valves which allow the inspired air to come to the subject (left) and the expired air to leave the body (right). The metal framework supports a can of soda lime surmounted by a rubber bathing cap. Measured amounts of oxygen are introduced into this cap through rubber bladders. One of these is filled and attached at the base of the can where a petcock may be opened to admit the oxygen.

behind each subject like a page. The cost of descending the stairway was found to be only about one third the cost of going up, or 5 times the cost of walking an equal horizontal distance.

(Courtesy of Dr. F. G. Benedict)

FIG. 17.—Determining, by Douglas Bag, the Energy Cost of Sawing Wood.

It is evident, then, that for practical purposes we need some way of expressing grades of activity, to indicate the relative severity of their demand upon the muscles. Atwater, in his experiments with the respiration calorimeter, used a stationary bicycle (ergometer) which could be adjusted to work against different degrees of electrical resistance; and with this he was able to compute the mechanical work actually done by his subjects, as well as their heat production, oxygen consumption, and carbon dioxide output. Atwater thus describes one of his early experiments to determine the influence of work:

"In the rest experiment the subject was as quiet as he well could be. In the four days of the preliminary period he moved about but little and engaged in no considerable amount of either muscular or mental labor. During the four days passed in the chamber he was likewise quiet. The only muscular work done was that involved in dressing, putting up and taking down the folding chair, table, and bed, weighing himself and the absorbers, taking his meals, and caring for the excreta. He passed a large part of the time in reading and sleeping.

"In the work experiment the subject was engaged in active muscular labor. The energy of the external muscular work done was entirely transformed into heat within the chamber. The larger part was first transformed into electrical energy by a small dynamo which was belted to the wheel of a stationary bicycle, and was then transformed into heat by an electric lamp through which the current passed. A small portion was converted into heat by the friction of this bicycle dynamo or ergometer. The heat thus produced was measured with the heat given off from the body." [1]

The table on page 47 shows the resulting figures.

With the bicycle ergometer, Benedict and Carpenter later (1917) studied the work done by a professional bicycle rider. In a "ride" of four hours and twenty-two minutes he ac-

[1] Atwater, W. O., and Rosa, E. B. *Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body.* Office of Experiment Stations, Bulletin No. 63, U. S. Department of Agriculture, page 76 (1899).

	Day	Calories
Rest experiment:	1	2,348
	2	2,263
	3	2,302
	4	2,326
	Average	*2,310*
Work experiment:	1	4,060
	2	3,788
	3	3,833
	4	3,639
	Average	*3,830*
Calories representing work		1,520

complished a "century run" (or over 100 miles), expending on the average 9.75 calories per minute (585 per hour), which

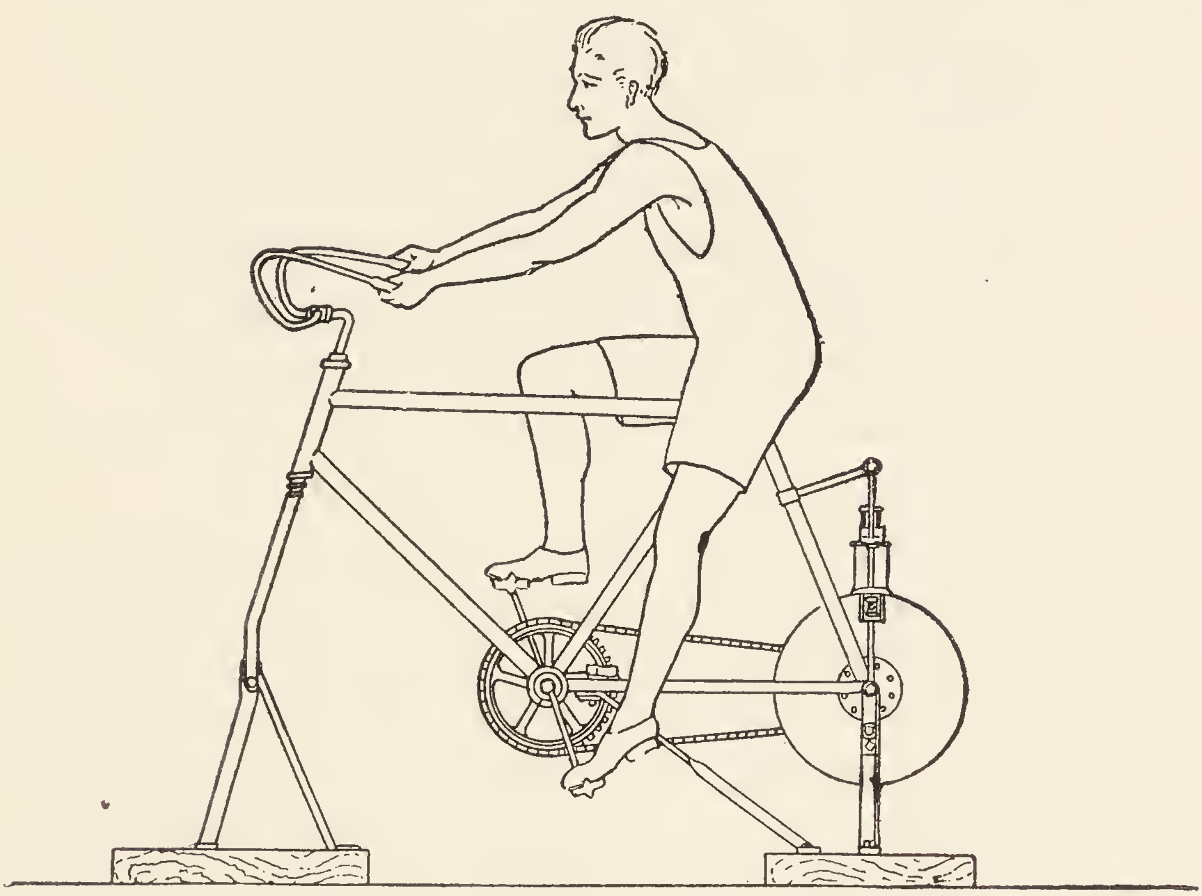


Fig. 18.—The Bicycle Ergometer.

A high-grade bicycle frame is mounted on a baseboard. In place of the rear wheel is a motorcycle hub fitted to a copper disk, and connected with this disk is an electromagnet. To increase the amount of work done the magnetic drag upon the disk is increased. The revolutions of the pedals are counted by means of a mechanical counter attached near the pedal-wheel hub.

was two and one half times as much as when simply sitting on the bicycle and revolving the freely moving wheel. Another sustained effort even greater than this is recorded by Robinson, manager of the Pike's Peak Hotel and long accustomed to mountain climbing, who in two hours and thirty-one

minutes ascended Pike's Peak from Manitou, 8.9 miles, the difference in altitude being 7,485 feet. His estimated energy expenditure was about 12.8 calories per minute (767 per hour).

For short periods, still more amazing feats of energy transformation have been accomplished by the human engine. By severe muscular work the energy output may be increased ten times in two minutes. A study of the maximum physical power of highly trained athletes was made by Henderson and Haggard on the Yale University boat crew which won the Olympic championship at Paris in 1924. No exertion calls into play so large a proportion of the muscular tissue as rowing. The stroke, repeated thirty or more times a minute, begins "in extreme flexion of trunk and legs, with a powerful drive of the extensor muscles, the strongest chain of muscles in the body; it then passes rapidly to extreme extension, pulling throughout against the high resistance of the oar, and ends with a powerful flexion of the arms. From this position the recovery involves a rapid bending of the wrists, lowering the hands and shooting them forward, and a bending of ankles, knees, hips, waist and shoulders, with contraction of practically all the flexor muscles to these joints." The work was measured in three ways: (1) a racing shell with a crew with an average weight of 172 pounds was towed by a motor boat, with a spring balance attached to the launch and the towline so that the "pull" of the shell and crew could be weighed at the same time that speed was noted; (2) an oarsman "rowed" so many strokes per minute on an apparatus in which the "oar" worked a pump and forced water against a resistance; and (3) the total energy expenditure of a man on the rowing machine was determined from oxygen consumption and carbon dioxide output. The energy expended by the men, who weighed from 154 to 185 pounds, ranged from 19 to 30 calories per minute (at the rate of 1,140 to 1,800 per hour). The lower figure represents the maximum which a man can maintain for 22 minutes during a four-mile race; the higher, for about 6 minutes in races of

about one and one third miles. The energy expenditure of the oarsmen in action was thus 13 to 20 times the basal metabolism.

The foregoing are but a few striking examples of experiments to determine the energy expenditure during muscular

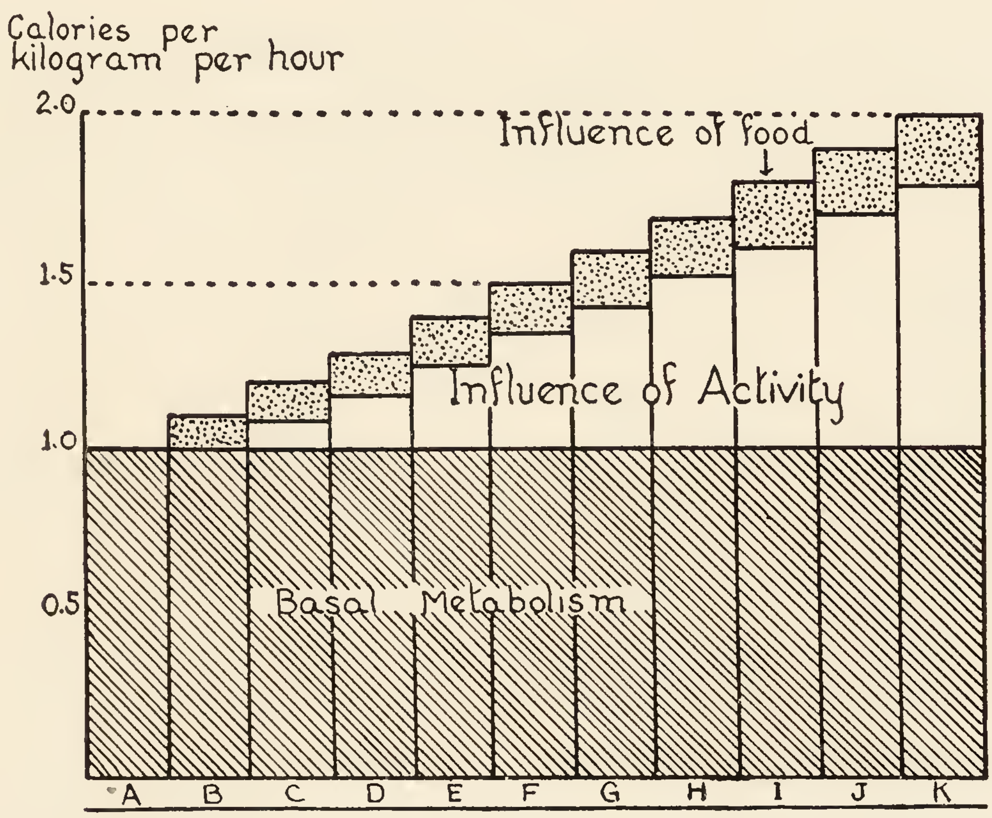


Fig. 19.—Changes in Energy Output Due to Increasing Muscular Activity.

State of Activity	Calories per Kilogram per Hour
A. Lying absolutely still, no food taken (basal metabolism)	1.0
B. Lying absolutely still, food taken	1.1
C. Sitting absolutely still	1.2
D. Lying quietly in bed	1.3
E. Sitting at ease	1.4
F. Standing relaxed	1.5
G. Standing "at attention"	1.6
H. Singing	1.7
I. Dressing	1.8
J. Ironing with 5-pound iron	1.9
K. Walking very slowly (about 1 mile per hour)	2.0

work, in which nutrition literature abounds. Figure 19 shows how even changes of posture and light muscular effort quite definitely increase the energy output.

In more general terms, we may grade activity as to whether it is "light," "moderate," or "severe." In such a classification it is customary to apply the term "moderate" to work which is equivalent to that of a carpenter laboring

at least 8 hours. In this category, "very light" or "light" exercise would be that involving few muscles, as in tailoring or typewriting; "severe," that involving many muscles and much effort, as in sawing wood; and "very severe" may be regarded as equivalent to running at the rate of five miles an hour.

Energy Expenditure for Different Grades of Muscular Activity

	Calories per Kilogram		Calories per Pound per Hour
	Per Hour	Per Day	
Sitting at rest	1.4	33.6	0.7
Very light exercise	1.9	45.6	0.9
Light exercise	2.4	57.6	1.1
Moderate exercise	4.1	98.4	1.9
Severe exercise	6.4	153.6	2.9
Very severe exercise	8.6	206.4	3.9

The Saving of Energy in Sleep

The true basal metabolism of an adult represents a condition of complete muscular repose with the brain active. What happens when the person is in complete muscular repose and at the same time asleep? One investigator so completely mastered the art of assuming at will a state of complete muscular relaxation that he found no difference between his basal and his sleeping metabolism. It is possible, however, that another person, who has achieved the greatest voluntary muscular relaxation of which he is capable, may exhibit a basal metabolism somewhat above the sleeping level because such influences as light and sound can act reflexly to increase the tonus of the muscles. This is well illustrated by Benedict's observations on Levanzin, the man who fasted in his laboratory thirty-one days. The investigator says: "A study of prolonged fasting recently carried out in this laboratory afforded an excellent opportunity for comparing the metabolism during the night when the subject was sleeping quietly in the bed calorimeter with that of the next morning when he was lying quietly upon the same bed, awake and breathing into the universal respiration apparatus. The subject slept for the greater part of the period

of observation in the bed calorimeter, the graphic record of the body movements made by the self-recording bed showing that the man was remarkably quiet throughout the whole night. During the morning observation, he was phenomenally quiet, the graphic record showing a practically straight line in every experiment. According to the opinion of Dr. T. M. Carpenter, who made the observations with the respiration apparatus, the subject had the most complete muscular relaxation and control of any of the individuals that he had ever studied." [1]

The metabolism of the subject while in the bed calorimeter during the night was compared with his metabolism immediately afterward when he was connected with the respiration apparatus in the morning, and was always higher after waking, the increases varying from 4.5 to 27 per cent.

The same investigators compared the metabolism of a number of men when lying awake in the forenoon, covered with a blanket in a cot, with that of the period from 1 A. M. to 7 A. M. when the subjects were in the same position but asleep.[2] The best three experiments showed an increase during the lying awake period amounting to about 11 per cent. Frequent observations of the pulse rate in the two conditions showed during sleep a decreased heartbeat and respiration rate, corresponding with the lower metabolic rate.

Every one realizes that sleep is not equally profound at all times, and that during sleep there may be muscular movements which would be suppressed were one awake and having his basal metabolism determined. This tendency to slight muscular movements may well account for some of the variations in sleeping periods, even with the same subject. Furthermore, what one has been doing previous to falling asleep may have some influence. In many of the experiments of Benedict and Carpenter with the respiration calorimeter at Wesleyan University the night periods were pre-

[1] Benedict, F. G. "Factors Affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 287 (1915).

[2] Benedict, F. G., and Carpenter, T. M. *Metabolism and Energy Transformations of Healthy Man During Rest.* Carnegie Institution of Washington, Publication No. 126 (1910).

ceded by day periods in which the muscular activity varied greatly, and there was a tendency for the heat output to be greater on nights following work upon the bicycle ergometer than on nights following days of rest. Thus two subjects after moderate exercise and two after severe exercise showed a sleeping metabolism 7 to 8 per cent higher than their sleeping metabolism after rest, and one after severe exercise a metabolism 20 per cent higher. It is customary to allow for sleeping after moderate activity a saving of about 10 per cent of the basal metabolism, or 0.1 calorie per kilogram per hour.

Estimating the Total Energy Requirement

We now have data from which we can estimate the energy requirement of a given individual with sufficient accuracy for most dietary purposes. Let us take Miss A., a college student, weighing 123 pounds, or 56 kilograms. Her daily schedule will not include much muscular activity, as much of her time will be spent sitting in classes or in reading in the library or perhaps in writing. By keeping a diary of her activities through the day, a table can be made giving the total time for each activity. Thus, dressing in the morning will take perhaps half an hour, changing for an afternoon tea, twenty minutes, and undressing and an unhurried bath at night, an hour and five minutes. All the time spent in dressing and undressing, therefore, amounts to one and three fourths hours. Time for other activities is estimated in the same way.

By using such factors as shown in connection with Fig. 19 for each kind of activity the cost of all the activities of the day can be calculated. By adding to these the calories of the basal metabolism, deducting the calories saved during the hours of sleep, and adding to the sum of all three 6 per cent of this total for the influence of food, we can arrive at a very satisfactory estimation of the total caloric requirement for the day. The calculations are given in detail below. For factors for many kinds of activity see Table IX, in the Appendix.

Estimate of Energy Requirement for One Day

I Activity	II Factor (Cal. per Kg. per Hr.)	III Time Hrs.	IV Cal. per Kg. II x III
Awake, lying still	0.1	0.50	0.05
Sitting	0.4	1.25	0.50
Standing relaxed	0.5	0.75	0.38
Sitting, writing, or eating	0.4	8.00	3.20
Standing at attention	0.6	0.25	0.15
Dressing and undressing	0.8	1.75	1.40
Light exercise	1.4	1.00	1.40
Walking slowly	1.8	1.00	1.80
Active exercise	4.1	1.00	4.10
Moderate walking	3.2	1.00	3.20
			16.18

Body weight, 56 kg.
Total calories for activities per kg. (sum of column IV), 16.18 Cal.
Total cost of activities (body weight in kg. x 16.18 Cal.), 906 Cal.
Saving in sleep (sleeping time x 0.1 Cal. per kg.), 42 Cal.

Total for Day

	Calories
Basal metabolism for 24 hours	1,300
Saving in sleep, to be deducted	42
Corrected basal metabolism	1,258
Cost of day's activities	906
Total cost of metabolism	2,164
"Tax" for influence of food (6 per cent)	130
Day's requirement	2,294

Total Energy Requirement in Terms of Calories per Kilogram of Body Weight

To compare the energy requirement per day of persons of different body weights it is necessary to reduce them to a common denominator of some sort. We may divide the total for the day by weight in kilograms and thus get calories per kilogram per day. Studies made by several hundred women students at Teachers College of their energy expenditure for a typical school day enable one to predict that the students with lowest activity will need about 33 calories per kilogram per day, while even the most active, being unable

as students to escape a number of hours in the classroom, will seldom require more than 42 to 45 calories per kilogram. A man engaged for an eight-hour working day in such vigorous exercise as sawing wood will expend twice as much per kilogram per day as a very quiet student. Extensive studies of the food consumption of people of various classes indicate that those performing like amounts of work will have about the same average metabolism. Women at sedentary occupations, as milliners, stenographers, and teachers, need about as much per day as quiet students, i. e., generally from 2,000 to 2,200 calories per day, or 33 to 38 per kilogram. Farmers, whether American, Mexican, Italian, or Finnish, require about 3,500 calories per day, or 50 calories per kilogram and United States soldiers in hard training about 4,000 calories per day. Few workers exceed an average of 70 calories per kilogram. For the man or the woman of average height and weight the total energy requirement for twenty-four hours will vary according to the type of occupation somewhat as follows:

Daily Energy Requirement According to Occupation

Type of Occupation	Total Calories per Day		Cal. per Kg. per Day
	Men	Women	
At rest but sitting most of day	2,000–2,200	1,600–1,800	30–33
Work chiefly done sitting	2,200–2,700	1,900–2,200	34–37
Work chiefly done standing or walking	2,800–3,000	2,300–2,500	38–42
Work developing muscular strength	3,100–3,500	2,600–3,000	43–50
Work requiring very strong muscles	4,000–6,000	....	55–70

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CHAPTER IV

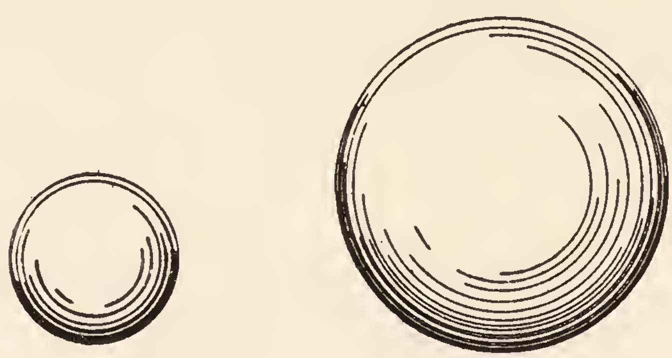
FACTORS CAUSING VARIATION IN THE BASAL METABOLISM OF INDIVIDUALS

Section I

FACTORS DUE TO BUILD, TEMPERAMENT, AGE, AND SEX

Influence of Size and Shape

For most practical purposes we can disregard fatness or thinness in adults if we estimate basal metabolism on the



A B

Fig. 20.—Two Balls Showing How, Shape Being the Same, Difference in Size Affects the Amount of Surface.

	A	B
Diameter	1 inch	2 inches
Surface area	3.14 square inches	12.57 square inches
Volume	0.52 cubic inches	4.19 cubic inches
Surface to volume	6:1	3:1

basis of body surface. If, however, we make calculations in terms of body weight, we shall find that we cannot apply our average of approximately one calorie per kilogram per hour without some error in those cases in which the individual is taller, shorter, thinner, or fatter than the average. Basal metabolism being more closely correlated with surface than with weight, we must consider what effect changes in size have on the relationship between it and weight. A small body has a greater surface in proportion to mass than a

large one. If we take two balls, one of them one inch in diameter and the other two inches, the first (A) will have a surface of 3.14 square inches and the other (B) of 12.57 square inches, while the volume of the first will be 0.52 cubic inch and that of the second 4.19 cubic inches. So the surface of the smaller ball in proportion to its volume is 3.14 to 0.52 or 6:1 and that of the larger ball is only 12.57 to 4.19 or 3:1. This means that if two animals alike in shape had the same relation to each other as these spheres, the smaller would produce twice as much heat per unit of weight as the larger.

In a similar manner we may inquire how the relationship between mass and surface is affected by shape. If we take a pound of modeling clay and make it into a cylinder (A) with a diameter of 2.6 inches it will have also a height of 2.6 inches; if we take another pound and make it into a cylinder with half the diameter of A, this one (B) will have a height of 12.2 inches. While the weight is the same in both cases, the difference in shape results in a difference in surface area, the tall and slender figure having a surface exposure of 48.3 square inches, while that of the shorter figure is only 31.8 square inches. In other words, the tall "thin" figure has half again as much surface area as the short "fat" one of the same weight.

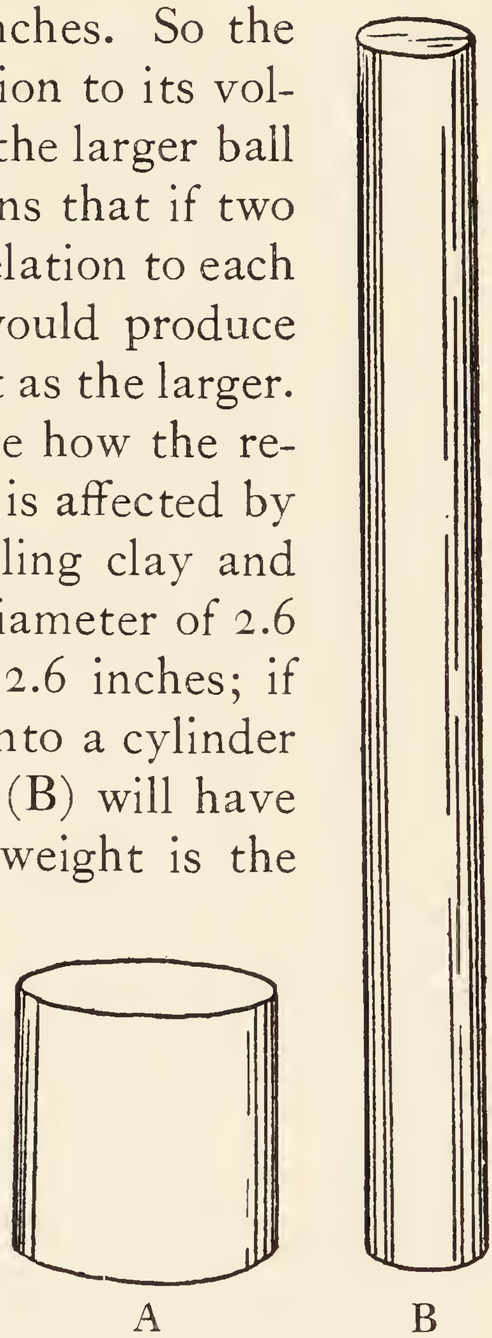


FIG. 21.—Two Cylinders Showing How, Weight Being the Same, Difference in Shape Affects the Amount of Surface.

	A	B
Weight	1 pound	1 pound
Diameter	2.6 inches	1.3 inches
Height	2.6 inches	12.2 inches
Surface area	31.8 square inches	48.3 square inches

If we take two men of about the same age and the same body weight but one much taller than the other and determine the basal metabolism of each for twenty-four hours,

we can see how this is related to body weight and to surface in human beings.[1]

Basal Metabolism of Two Men of the Same Weight but Different Height

Subject	Age Yrs.	Height Cm.	Body Weight Kg.	Surface Area Sq. M.	Basal Metabolism for 24 Hrs.		
					Total	Cal. per Sq. M.	Cal. per Kg.
Mr. B.	41	183	83.1	2.06	1,802	875	21.7
Mr. C.	36	169	83.0	1.89	1,655	876	19.9

On the basis of body surface the metabolism is the same, but when we calculate this to calories per kilogram of body weight, the taller figure shows a metabolism higher by 9 per cent.

A similar interesting comparison may be made between individuals of the same height but differing in body weight.

Basal Metabolism of Three Men of the Same Height but Different Body Weight

Subject	Age Yrs.	Height Cm.	Body Weight Kg.	Surface Area Sq. M.	Basal Metabolism for 24 Hrs.		
					Total	Cal. per Sq. M.	Cal. per Kg.
Mr. C.	36	169	83.0	1.89	1,655	876	19.9
Mr. E.	26	169	57.0	1.65	1,531	928	26.9
Mr. W.	22	169	57.8	1.66	1,472	887	25.5

Mr. C. is 46 per cent heavier than Mr. E. or Mr. W. (who are almost exactly the same weight) and his surface area is 14 per cent greater than theirs. The metabolism per square meter of surface differs but little for the three; on the basis of calories per kilogram the metabolism of Mr. E. is almost the same as Mr. W., but both are 32 per cent higher than Mr. C.

Influence of Body Composition

Two individuals of exactly the same weight and height and consequently of the same surface area may still differ somewhat in the intensity of their basal metabolism. The

[1] The data used in these illustrations are taken from Benedict, F. G. "Factors Affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 282 (1915).

explanation lies in the fact that the great seat of energy exchange is the muscle tissue, and that bone, fat, and water, while inert so far as energy metabolism is concerned, still play a part in determining weight. The large fat person not

The Basal Metabolism of Men and Women of Approximately the Same Height and Weight Showing the Lower Metabolism of Women [1]

Sex	Height Cm.	Weight Kg.	Area Sq. M.	Total Calories	Difference Per Cent
M	164.0	54.6	1.58	1,524	
F	163.9	54.8	1.58	1,248	18.1
M	173.4	56.7	1.68	1,644	
F	170.0	56.1	1.64	1,390	15.5
M	154.3	60.8	1.58	1,526	
F	154.5	60.6	1.59	1,302	14.7
M	168.3	66.3	1.76	1,849	
F	168.5	65.3	1.73	1,598	13.6
M	167.1	67.5	1.75	1,593	
F	166.2	67.0	1.73	1,402	12.0
M	162.5	68.0	1.72	1,680	
F	163.8	68.0	1.74	1,401	16.7

only has a size and shape favorable to an economical energy expenditure per unit of weight, but also has less muscle tissue in proportion to his bulk. Athletes, having by vigorous exercise rid themselves of surplus fat and built up firm muscle tissue, show a basal metabolism about 6 per cent higher than nonathletic individuals carefully paired with them as to size and shape. Women, with a higher proportion of body fat, have on the basis of body surface an average metabolism about 14 per cent lower than that for normal men, as shown by the table above.

Influence of Muscle Tension

In making a determination of basal metabolism on any person, every effort is made to have as complete muscular

[1] Data from Boothby, W. M., and Sandiford, I. "Summary of the Basal Metabolism Data on 8,614 Subjects with Especial Reference to the Normal Standards for the Estimation of the Basal Metabolic Rate." *Journal of Biological Chemistry*, Vol. 54, page 791 (1922).

relaxation as possible. This is one reason why the basal metabolism is determined early in the morning; even under quiet conditions, tension becomes higher as the day progresses. If the person has risen from bed, dressed, perhaps traveled to the laboratory, he is required to lie quietly for a time to let the effect of exercise upon the tone of the muscles wear off. It is also important that he be in a calm frame of mind, as emotion will raise the muscle tension. If proper precautions be observed in making laboratory tests, most of the determinations on normal men will fall within 10 per cent of the average.

Influence of Mental States

As has already been pointed out, the chief seat of energy exchange is the muscles. We have seen how under the stimulus of cold they may, without our knowing anything about it, increase their tension (do more work) and give off more heat. The seat of thought is the nervous tissue. Do we increase our energy expenditure when we think?

The classic demonstration that mental activity does not materially change the metabolic rate was made by Benedict and Carpenter with the respiration calorimeter. In it twenty-two young college men took three-hour examinations and later sat the same length of time copying printed material which required no mental effort. The metabolism was only slightly greater in the first case than in the second.

Recently some very interesting measurements of the effect of mental exertion have been made by Dr. and Mrs. Benedict. The mental effort consisted in solving, without writing or talking aloud, certain mathematical problems, a typical one being to multiply 73 by 47. The problems were given orally, and at the completion of each the subject touched a telegraph key. Problem followed problem as rapidly as solved. The general effect of the mental exertion was the same in all of the seven cases. It was found that the mental effort of multiplying "in the head" increased the metabolism 3 or 4 per cent. Commenting on this work, they say: "The pro-

fessor absorbed in intense mental effort for one hour has an extra demand for food or for calories during the entire hour not greater than the extra needs of the maid who dusts off his desk for five minutes. The cloistered scholar at his books may be surprised to learn that the extra calories needed for one hour of intense mental effort would be completely met by the eating of one oyster cracker or one half of a salted peanut." [1]

Tashiro, a Japanese investigator working at the University of Chicago, has shown by an exceedingly delicate apparatus for measuring carbon dioxide excretion that when an impulse is transmitted along a nerve the carbon dioxide production may be increased to two and one half times that of the resting nerve. If we should assume all the nervous tissue in the body to be as active as this, the total carbon dioxide output would not equal that produced by lifting one's hand to one's face. As the nervous tissue is only about 2 per cent of the total body weight, even if its metabolism increased with thinking, the total would be small, the highest estimate of the energy metabolism of the brain being only 10 per cent of the resting metabolism. Students sometimes ask, "Why do we get hungry when we study?" forgetting that they would get hungry anyway. They are generally more active in their periods of relaxation and actually need more food on holidays than on study days.

Aside from the question of the basal metabolism of the nervous system itself, mental states are, however, not without influence upon the muscles. As Stiles says, "an emotional experience is much more than a cerebral phenomenon." It is a form of exercise. Increased heart action, more rapid respiration, tenser muscles are characteristic of more than one emotional state, and in experimental hypnosis, normal men and women have responded to suggestions inducing fear or joy with increased heat production which seems to be the direct result of the changed emotional condition. The

[1] Benedict, F. G., and Benedict, C. G. "The Energy Requirement of Intense Mental Effort." *Science*, Vol. 71, page 567 (1930).

evidence on this point is still meager and here, again, the average increase is under 10 per cent.

Influence of Internal Secretions

One of the very fascinating fields of modern physiology is that embracing the endocrine glands, which deliver to the blood internal secretions containing hormones (sometimes called chemical messengers) which are quite as important as the nervous system in keeping all parts of the body working harmoniously together. These hormones are chemically very powerful so that minute quantities introduced into the circulation produce remarkable effects. Thus absence in childhood of thyroxin, the hormone of the thyroid gland, results in failure to grow physically or mentally; a superabundance of one of the several hormones of the pituitary gland brings about abnormal growth and a giant may develop; or again, failure of the pancreas to produce insulin is attended by impairment of the body's power to use its fuel foods in the normal way, and a disease marked by undernutrition, called diabetes mellitus, ensues.

Of all the glands of internal secretion, the thyroid has the closest connection with the energy exchange. In health it may be regarded as responsible in large measure for the constancy of the normal basal metabolism. In diseases of the thyroid characterized by overproduction of thyroxin, the chemical processes of the body are speeded up, and the basal metabolism may in very severe instances increase as much as 75 per cent. Moderately severe cases will show increases of from 40 to 50 per cent, while in mild cases the rise may still be from 15 to 30 per cent. On the other hand, a subnormal production of thyroxin causes a lowering of the basal metabolism, in severe cases amounting to a fall of as much as 30 per cent. So characteristic of thyroid disturbance is a change in the basal metabolism that a quantitative test of energy expenditure is one of the routine measures in the clinical diagnosis of thyroid disease. Deviations of 10 to 15 per cent from the normal average are not by themselves

significant, such variation occurring in normal persons, and no single determination is ever to be regarded as conclusive. The amount and nature of the change must be studied in connection with all other factors in the situation.

In addition to a high basal metabolism, the patient suffering from hyperthyroidism is in a state of almost incessant movement. Consequently his total food requirement may be so high that only when resting in bed can he eat enough food to compensate for his high energy output. If he attempts any muscular work, this is done with difficulty and at a cost of twice the calories required for the same work by a normal man. Hyperthyroidism tends to bring the person very quickly to a state of undernutrition and the only remedy is reduction of the production of thyroxin by suitable treatment in which rest is always a prominent feature.

The adrenal gland secretes two hormones, cortin from the outer rind or cortex and adrenalin from the central core or medulla. Cortin has no direct influence on the energy metabolism, but an injection of adrenalin, also called epinephrin, will cause a rise proportional to the dosage. Its effect is much less powerful than that of thyroxin. A single dose of one milligram of thyroxin, the effect of which will be spread over a period of several weeks, will cause an extra energy production of 1,000 calories, while one milligram of adrenalin will cause an extra output of only 50 calories and its influence may reach its height in an hour. The effects of adrenalin are more immediate and transient than those of thyroxin, the latter reaching its maximum effect slowly and continuing to stimulate metabolism for a considerable time. Professor W. B. Cannon of Harvard University has shown that under stress of emotional states, as fear, rage, or pain, the adrenals are stimulated to an increased output of adrenalin, the heart action becomes more vigorous, blood is shifted to the organs immediately necessary for muscular action and these are put under greater tension, so that the body has power to carry out any of the actions that may take place under the force of these emotions. All this means

a temporary increase in the basal metabolism. Muscular action alone causes some increase in adrenalin production, but the most profound effect is from emotion and vigorous muscle action together. Cold also stimulates adrenal activity, which in turn causes increased heat production as discussed under influence of temperature. After complete removal of the adrenal glands there is great relaxation of the whole muscular system and the basal metabolism falls. In cats observed 48 hours after adrenal removal, there was a fall of 25 per cent and similar effects have been observed with dogs. Following injection of the extract of the adrenal cortex, animals which recover gain rapidly in weight, their appetite returns, and the energy metabolism returns slowly to normal. The effect seems to be indirectly due to the improved general nutrition, i. e., recovery from severe undernutrition, rather than to a specific effect of cortin, since there is no change induced in the energy metabolism of a normal animal within twenty-four hours after injection.

The basal metabolic rate of human beings has been found somewhat low in many cases of subnormal functioning of the pituitary gland or hypophysis. Experimentally, removal of the anterior lobe of the gland has been found to decrease the basal metabolism of rats as much as 29 per cent. The discovery of a specific hormone (the thyrotrophic) in the secretion of the anterior lobe has made it evident that the influence of the pituitary gland on metabolism is exerted chiefly through the stimulation of thyroid activity by this hormone. Another hormone of the anterior lobe (the adrenalotrophic) influences the adrenal gland and may also be a factor in changes in the basal metabolic rate in pituitary disturbance. At the present time there is no evidence of any other hormone acting specifically as thyroxin and adrenalin do.

Influence of Age

The influence of age during the period of growth will be considered in Chapter V. This discussion is confined to

adults. For practical purposes the metabolism of men and women between the ages of twenty and forty years may be regarded as nearly constant. Whatever change may occur is manifest only over a long period, as is evident from DuBois's suggestion that in a laboratory, for a check on the reliability of the respiration apparatus, "one or two of the normal controls who are readily available should be studied at frequent intervals throughout the year, since they should maintain a fairly constant metabolism."

Harris and Benedict from a statistical study of adult men and women conclude that for each year of age after twenty a man's decrease in total heat production amounts to 7.15 calories per day; i. e., if at twenty a man has a metabolism of 1,735 calories per day, at twenty-one it would be 1,728 calories; at twenty-two 1,721 calories. For a woman, the decrease is estimated to be only 2.3 calories per day for each year of age. While this annual fall is slight, in forty years it results in an appreciable lowering of the energy expenditure.

A study of 23 aged women was made by Benedict and Meyer [1] in a home for elderly women in Boston. All but two of the subjects were at least 70 years old and ten ranged from 78 to 86 years. For the comfort of the old ladies, a helmet type of apparatus was used, a pail-shaped vessel with a small window for the benefit of the subject being inverted over the head and made air tight about the neck by a thin rubber collar. The usual connections were made with a spirometer supplying oxygen, the carbon dioxide was removed by means of a jar of soda lime, and a small fan served to keep the air in the closed circuit in circulation. The average basal metabolism for the group was 729 calories per square meter of body surface per day as compared with the Harris-Benedict average of 760 calories per square meter per day for women from 50 to 60 years of age. It is interesting to note that the total basal metabolism of the ten

[1] Benedict, F. G., and Meyer, M. H. "The Basal Heat Production of Elderly Women." *Proceedings of the American Philosophical Society*, Vol. 71, page 143 (1932).

women 78 years and over was close to 1,000 calories per day regardless of considerable differences in body weight.

In a study of men past seventy-five years of age made by Aub and DuBois the heat production was found to be 10

(*Courtesy of Dr. F. G. Benedict*)

FIG. 22.—Determining the Basal Metabolism with a Helmet Enclosing the Head, Instead of a Mouthpiece and Nose Clip.

to 14 per cent less per square meter of surface than the average for men between thirty and forty. The following table is based upon one given by them to indicate the trend with increasing years. The figures for women have been corrected

according to our present knowledge that the original ones were about 7 per cent too high.

Basal Metabolism of Adults at Different Ages

Age Years	Calories per Sq. M. per Hour		Calories per Sq. M. per Day	
	Men	Women	Men	Women
20–30	39.5	34.4	948	826
30–40	39.5	33.9	948	814
40–50	38.5	33.5	924	804
50–60	37.5	32.5	900	780
60–70	36.5	31.6	876	758
70–80	35.5	30.7	852	737

Influence of Sex

The sex glands have secretions which account for certain sex characteristics, but no clearly defined differences in basal metabolism due to sex hormones have been produced experimentally. Women, as has already been stated, have a basal metabolism about 14 per cent lower than that of men of corresponding age. Menstruation has little influence, changes which occur ranging from 2 to 5 per cent. Castrated males tend to have the higher body fat which characterizes women as a class; but there is no evidence that a total absence or diminished activity of the sex glands regularly causes a decrease in the metabolic rate.

Influence of Pregnancy

A mother's gain in body weight during pregnancy totals, on the average, about 30 pounds. During the early months weight tends to remain stationary, while in the last three months gains range from 3.5 to 5.5 pounds per month. About half the gain is due to general increase in body tissue on the part of the mother herself. A detailed study of a pregnant woman made by her husband [1] showed that after the fourth month the basal metabolism rose slowly, until a few days before delivery it was about 23 per cent above what it was in the fourth month. Murlin, Professor of

[1] Root, H. F., and Root, H. K. "The Basal Metabolism during Pregnancy and the Puerperium." *Archives of Internal Medicine*, Vol. 32, page 411 (1923).

Nutritional Physiology in the University of Rochester, has shown that the energy metabolism of a mother and child together a few days after parturition just about equals that of the mother before confinement. He found a striking instance of this relationship between parent and offspring in two experiments with a dog that bore at one time a litter of one pup and at another a litter of five; the extra calories attributable to the lone pup were 46 (164 per kilogram) and to the five pups, 258.5 (165 per kilogram).[1] Interpreting his observations in terms of body weight, Murlin estimates that for the human mother the basal energy metabolism per kilogram per hour is only about 4 per cent higher than for the same woman before pregnancy. For practical purposes the increase in metabolism may be assumed to parallel fairly closely the increase in weight.

Section 2

THE RELATION OF TEMPERATURE REGULATION TO BASAL METABOLISM

A frog's body temperature changes as the thermometer rises or falls. On a cold day the animal is cold; on a warm day it is warm. When its body is cold, metabolism is reduced; when its body is warm, metabolism is increased. The difference between 4° C. (winter) and 30° C. (summer) may cause an increase of 400 per cent in the amount of carbon dioxide produced. A man's body temperature is practically constant (close to 37° C.), regardless of the external temperature. Changes in the normal person's body temperature in the course of a day scarcely exceed one degree Fahrenheit, while in a single hour the temperature of the environment may rise or fall many degrees. In Texas, a drop of 40° F. in one hour is not uncommon; in New York in August one may step from the hot summer street into the artificially cooled theater. How do these changes in temperature affect the basal metabolism?

[1] Murlin, J. R. "Normal Processes of Energy Metabolism." Barker's *Endocrinology and Metabolism*, Vol. 3, page 622. D. Appleton and Co. (1922).

To get to the root of the matter, we must first rule out the influence of housing and clothing, which may greatly modify the situation. About 80 per cent of the heat usually produced in the body is lost through the skin. If we take a man's basal metabolism without clothing in a room only slightly below body temperature (30° C. or 86° F.), free from drafts or changes in humidity, there is then no thermal stimulus to metabolism. Atwater has shown the heat loss of a resting man to be as follows:

	Calories
1. By radiation and conduction	1,683
2. By urine and feces	31
3. By evaporation from lungs and skin	548
Total	2,262

The path of heat elimination varies with the environment. There is little evaporation of water when the temperature is low; and, since there is no opportunity for loss of heat by radiation and conduction when the surrounding atmosphere has a temperature as high as or higher than the body, water evaporation must remove all the heat.

Effect of High Temperature Including Fever

What happens when the temperature of the environment becomes equal to that of the body? If the person is free to perspire and the humidity of the atmosphere does not interfere with the evaporation of the moisture on the skin, there will be no change in body temperature or in the rate of heat production; for as the evaporation of water cools the skin the blood beneath it will be cooled and, mingling with that from the interior of the body, will check the tendency to rising temperature. On the other hand, if we put a man into a bath at body temperature, there will be no way of getting rid of body heat—no chance for radiation, conduction, or evaporation; but the body will continue to produce heat and consequently the body temperature will rise. According to Stiles, 100 calories added to the average human body in an hour will raise its temperature nearly 4° F.

It is a recognized law of physics that the velocity of chemical reactions is accelerated at a definite rate by increasing temperature, and since the reactions in living cells are chemical this law applies to them; i. e., whenever body temperature rises heat production increases in direct proportion. A bath at 42° C. (107.6° F.) has been shown to cause an increase in the oxygen consumption amounting to 15 per cent. Studying the basal metabolism under a variety of conditions in which body temperature was above normal (fevers), DuBois has calculated that the increase in energy expenditure in fever amounts to 7.2 per cent for every degree Fahrenheit. What this means is readily seen from the following estimates on the basal metabolism of the average man:

Increases in Energy Expenditure with Rise in Body Temperature

Rise in Temperature, Degrees Fahrenheit	Increase in Energy Expenditure, Per Cent	Extra Calories Due to Elevation of Temperature
1	7.2	122
2	14.4	245
3	21.6	367
4	28.8	490

For the average bedridden person with normal temperature we ordinarily make allowances above the normal basal metabolism of 10 per cent for the movements inevitable through the twenty-four hour day, and of 6 per cent of the sum of basal metabolism and cost of activity for the influence of food. For an individual case the calculation would be as follows:

Energy Expenditure of a Bedridden Man with Normal Temperature

	Calories
Basal metabolism	1,700
Allowance for activity	170
Allowance for influence of food	112
Total for 24 hours	1,982

The fever patient must have an additional allowance for increased expenditure due to elevation of temperature on the basis of 7.2 per cent for each degree Fahrenheit and if

restless, a higher allowance (20 to 30 per cent) for activity. For an average man with fever the day's requirement would be estimated thus:

ENERGY EXPENDITURE OF A MAN WITH A FEVER, BODY TEMPERATURE ELEVATED 2° F.

	CALORIES
Basal metabolism	1,700
Increase for 2° F. rise in temperature	245
Total basal metabolism	1,945
Allowance for activity	389
Allowance for influence of food	140
Total for 24 hours	2,474

With only a moderately high fever the food requirement may easily reach 2,500 calories per day. Whether it is wise to try to meet this need fully with food or whether it is better for a time to let the patient burn his own body reserves is a point which the physician must decide for the individual case. But full realization of what it means for a patient to be burning 2,500 calories a day of his own body substance is important. If the energy requirement can be covered by food, the patient will be less weakened by his disease. This is most strikingly shown in the case of typhoid fever. There was a time when it was thought necessary to give very little food in spite of the fact that typhoid is a long wasting illness. The patient became so weak and emaciated that convalescence was almost as dangerous as the febrile state. But in 1909 Shaffer and Coleman, using the calorimeter of the Russell Sage Institute of Pathology at the Bellevue Hospital in New York City, were able to make careful studies of the energy metabolism in typhoid and to demonstrate that it was possible to feed typhoid patients a diet high enough in calories and protein to prevent all loss of body substance. The treatment of typhoid was revolutionized and patients fed according to Shaffer and Coleman's plan actually gained weight during the progress of the disease. The task of feeding typhoid patients is, how-

ever, peculiarly difficult since in addition to the allowance suggested for rise in temperature, there must be a large surplus of calories for the special purpose of preventing waste of the body tissues. To accomplish this, anywhere from 50 to 100 per cent more calories must be given than are necessary to meet the energy expenditure as estimated in the table on page 71.

Shaffer and Coleman were able to administer diets furnishing as high as 50 to 80 calories per kilogram with beneficial effect. Later experience has shown, however, that typhoid patients may do very well on diets supplying from 35 to 40 calories per kilogram. The greatest care must be taken to prevent any digestive disturbance or even the slightest irritation or distention of the alimentary tract. The diet must be prescribed with utmost care and the feeding regarded as a part of the nursing and of the utmost importance.

The metabolism in malarial fever is influenced by the chills as well as by the fever. The changes are best illustrated by one of the cases studied by Barr and DuBois, also with the calorimeter of the Russell Sage Institute.

Energy Changes in a Case of Malarial Fever

	Per Cent above Normal Basal Metabolism
One hour before severe chill, no fever	+14
Rising temperature before chill	+21
Violent chill (40 min.)	+216
Rising temperature after chill	+80
High constant temperature after chill (41.2° C.)	+71

In the preliminary period the heat output is only a little if any above normal, beginning to rise as the temperature rises before the chill. During the chill the violent muscular exertion increases heat production enormously. In the period following the chill the temperature is rising, but the percentage of energy output falls as compared with that during the chill. Later the temperature declines and gradually both metabolism and temperature return to normal.

In pulmonary tuberculosis there may or may not be fever. When the temperature is normal the basal metabolism is

usually though not always normal; but whenever the body temperature rises the energy output follows the general law and rises proportionately. Before studies of the energy metabolism in this disease had been made, the tendency was to feed very high calorie diets, but this is not necessary to maintain an energy equilibrium and it is desirable to reduce the strain on the lungs from the work of respiration as much as possible; consequently the total calories should be no more than necessary to meet the energy requirement (usually not over 2,500 calories per day) and a fairly high proportion should come from fat. Here again the diet needs to be carefully prescribed and faithfully administered, as the appetite is frequently poor, and digestion apt to be disturbed. DuBois [1] sums up the situation thus: "It is perfectly extraordinary how much food can be given to fever patients by a good nurse. In the first place, she takes scrupulous care of the mouth and teeth, realizing that no patient cares for food if his mouth is dry, his tongue cracked and his teeth dirty. She also takes care of the nose because if this is clogged the patient is forced to breathe through his mouth which soon becomes dried and parched. She sees that the bowels are thoroughly emptied each morning, using enemas if necessary. She studies the likes and dislikes of the individual patient and does not try to force foods which are distasteful even in health. She makes skillful use of substances such as lactose which can be added to liquid foods in such a manner that their presence is not detectable by the patient. She seizes opportunities at night to feed the patient when he is awake. Above all, she uses tact and employs persuasion or gentle firmness as the case demands."

Effect of Temperatures below That of the Body

If we start our study once more with a nude man resting in quiet air at 30° C. and proceed to reduce the temperature, what changes will occur in his heat production? Perspiration

[1] DuBois, E. F. *Basal Metabolism in Health and Disease*, 3rd edition, page 441. Lea and Febiger (1936).

begins to decrease and the peripheral blood vessels to contract so that less heat is lost. At temperatures only slightly under 30° C. there will be little change in the metabolism. As the thermometer continues to fall the feeling of "tone" develops in the muscles, meaning that the muscles, contracting more vigorously, are doing more work in order to generate more heat. How greatly the sudden stimulation of cold may affect the metabolism can easily be demonstrated by a cold shower. It has been found that at 15° C. (59° F.) a shower lasting from three and a half to five minutes more than doubled the oxygen consumption, and the metabolism thereafter falling gradually did not regain normal for an hour and a half.

This increase in response to the stimulus of cold is called "chemical regulation" of temperature, in contrast to those changes in heat loss which involve no change in metabolism and are grouped under the term "physical regulation."

How the chemical regulation is accomplished has been shown in the following manner by Cannon and his associates. When cold water or crushed ice is introduced into the stomach quickly, heat-producing factors must be set at work to restore body temperature. In other words, there is a "heat debt" incurred which must be paid. Such a debt may be met by doing extra work, i. e., by shivering, but it may also be met, if not too great, by increased secretion of adrenalin, which causes a faster metabolic rate in response to the body's need for heat. Thus for men and women taking ice cold water to create a heat debt of 0.449 calorie per kilogram of body weight, the average increase of metabolism was 16.4 per cent. When shivering occurs, the rise in heat production is sudden and much more marked and it may nearly double the energy output. When conditions are such as to induce shivering, they are also such as to induce a faster rate of adrenal secretion. Extra heat production as a consequence of a larger output of adrenalin would therefore coexist with the extra heat production due to muscular activity. But such regulation plays little part in the lives of many city dwellers

today. Cannon [1] sums up the situation thus: "It seems probable that the chemical mechanisms for heat production rarely come into service in the ordinary comfortable existence of civilized man. Persons who live through a winter in houses and public buildings, often kept unpleasantly warm, are subjected to few of the exigencies which their ancestors had to meet under primitive conditions. Even if a superficial feeling of being cold signals a possible danger of heat loss, warm clothing is at hand to protect against an amount of heat loss that would call the mechanisms into action. And furthermore, as a rule, the heat produced as a by-product of ordinary functioning of muscles and glands, when associated with quick voluntary protection against heat loss, would be adequate for the ordinary demands of cold weather as most of us have to meet them. If the artificial protection is lacking, however, or if it proves unequal to the occasion, the heat-producing mechanisms are ready, and can be brought into service promptly to help in the emergency."

Chemical regulation is involuntary, but we may voluntarily increase our heat production by increased muscular work. The man waiting on the curb for a car on a cold morning stamps his feet and claps his hands; the one walking to work sets off at a brisker pace than on a balmy day. The range of physical regulation is widely extended by clothing and housing, which will be referred to later.

Effect of Body Fat on Regulation of Body Temperature

A layer of subcutaneous fat acts much like a woolen or a fur garment. Rubner studied a dog when it was thin and again after it had been fattened and found that, while there was no difference at 22° C. (71.6° F.), there was nearly a fifth more heat produced by the dog in its thin than in its fat state if the thermometer was reduced to 15° C. (59° F.). When a thin man steps into a refrigerator his heat production is increased much more than is that of a fat man when he

[1] Cannon, W. B., Querido, A., Britton, S. W., and Bright, E. M. "Studies on the Conditions of Activity in Endocrine Glands. XXI. The Rôle of Adrenal Secretion in the Chemical Control of Body Temperature." *American Journal of Physiology*, Vol. 79, page 504 (1927).

enters it. At low temperatures, a layer of subcutaneous fat is very valuable in preventing rapid loss of body heat and saving the body from burning fuel merely to keep warm.

With rising temperatures, fat hinders heat loss and a fat man's body temperature is more likely to rise than a thin man's, because the former cannot easily dispose of heat by radiation and conduction. Therefore, the fat person is more liable to heat prostration than the thin individual and needs to be cautious about exercise which will produce heat when getting rid of it is difficult.

Relation of Season and Climate to Temperature Regulation

Besides temperature, we must consider wind and humidity as factors in the problem of the regulation of body temperature. An imperceptible air current has been shown to increase the heat loss of the exposed area of a man's arm from 19 to 75 per cent above that in absolutely quiet air, the exact amount depending upon the temperature of the current. A young woman exposed to the windy blasts of April in England was found to have nearly doubled her resting metabolism; adult men and women exposed to an Alpine winter climate in sheltered sun-boxes showed increases in metabolism varying from 38 to 79 per cent above basal rates taken in London; and children responded with still greater increases, varying from 72 to 225 per cent.

It must be remembered, however, that when any muscular activity, such as walking, for instance, furnishes heat as a by-product there is lessened need of special "chemical regulation." While a cold plunge induces shivering (chemical regulation), a swim in the same water may leave the body glowing because the work of swimming is severe enough to result in the production of heat in excess of that needed to maintain body temperature.

Humidity facilitates heat loss when associated with low temperature and wind, but hinders it when associated with high temperature, especially if the atmosphere be quiet. The fat person suffers most from high temperature with

high humidity, as what little cooling power the perspiration may have does not act as effectively through a covering of fat. In such a person, rise in body temperature easily occurs, with a resultant rise in the basal metabolism, adding further to the heat to be dissipated. Such a person works with difficulty in hot, humid weather, as each movement adds its quota of heat to the general discomfort.

Effect of Clothing and Housing

Man's triumph over every climate is due to his ingenuity in extending the realm of physical regulation through his dwelling and his garments. Even a rude hut protects from wind, wet, and heat, while a modern palace may maintain the same temperature when the thermometer outside stands at zero as when it stands at "ninety-five in the shade." Wherever there is cold, the home of civilized man is equipped with some kind of heating device, which greatly limits the work his muscles are called upon to do to keep him warm, and in the hot season the electric fan now creates artificial wind for the cooling of multitudes or air conditioning keeps the temperature of the modern house below that of the outer air, to the great comfort of all within its walls.

The variety of ways in which clothing is related to a life almost devoid of shivering or sweltering are too numerous to record here. Silk, cotton, wool, fur; thick cloth or thin, woven close or woven loosely; all have a part to play. It is wonderful to think that an Arctic explorer can lie down and sleep to awaken warm and even perspiring after an Arctic night with the thermometer 60° below zero (F.) and the wind blowing a gale, provided there is not the tiniest hole in his garment. The smallest opening would be fatal as it would mean a heat loss which no chemical regulation could ever offset!

In everyday life in temperate zones, those conditions which facilitate heat loss from the body are likely to raise the metabolism unless counteracted by clothing and housing. The seashore, with a cold moist wind, is ideal for cooling

the body rapidly. This is not necessarily a disadvantage, as the higher muscle tonus may be accompanied by a better appetite and the habit of eating more food become established so that it persists upon the return home after a seaside holiday. People who need to be fattened may benefit from having their basal metabolism raised by the climate, provided they can have enough food to more than meet the increased demand. When clothing is scanty and fails to conserve body heat and at the same time food cannot be found to meet the increased metabolism, the body is in danger of drawing upon its own substance for fuel. The poor suffer doubly from inadequate clothing and shelter because their food needs are thus increased. Their thinly clad children are apt to be undernourished; whereas, the thinly clad children of the rich may benefit from this stimulus to life on a higher metabolic plane, provided they are fed intelligently.

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CHAPTER V

THE ENERGY REQUIREMENT OF CHILDREN

Some Studies of Children's Energy Metabolism

So far we have been dealing with the energy needs of the healthy adult, whose basal metabolism varies but little from day to day or year to year, and whose total energy requirement is determined chiefly by size and muscular activity. We shall now consider the span of life from birth to maturity, in which age is the greatest single factor modifying energy needs.

The aphorism of Hippocrates, "Growing bodies have the most heat; they therefore require the most food," was based on accurate observation, but any quantitative measurements of the differences between the young and the adult were not forthcoming for twenty-five centuries. Fifty years after the death of Lavoisier, two other French investigators following in his footsteps conducted the first respiration experiments on children, using a copper mask attached to the child's face and collecting the expired air in large glass globes for subsequent analysis; Andral and Gavarret in 1843 thus studied twelve children between the ages of 8 and 16 years. About thirty years later (1877) the first observations on a baby's metabolism were made by Forster of Munich, whose work was inspired by that of Pettenkofer and Voit. He used a Pettenkofer-Voit respiration chamber just large enough to hold a child's cot and studied a number of children varying in age from 14 days to 13 years. In 1894, the first study of heat production during the initial week of life was made by Mensi of the Academy of Medicine in Turin, Italy. He placed the baby under a large glass bell in which the oxygen was replenished and measured as the infant used it up, and the carbon dioxide exhaled was absorbed and weighed.

At almost the same time (1895), in Stockholm, Sondén and Tigerstedt, who had constructed a very large respiration chamber to study the problem of ventilation of school buildings, took various groups of children between 8 and 15 years of age, sometimes boys, sometimes girls, who were induced by reading or eating apples (occasionally candy) to sit quietly for periods of four and a half hours, so that their carbon dioxide excretion might be determined. This was the first extensive study covering different ages of both sexes. A little later (1899) the first comprehensive study of the changes in the metabolism throughout the whole life cycle of the individual from childhood to old age was undertaken in Germany by Magnus-Levy and Falk. The children included 11 boys and 9 girls ranging in age from 2½ to 14 years. Although carried out nearly thirty years ago, this study was made with such skill that it is comparable with our best modern work.

In these and other experiments extending over nearly three quarters of a century, little attention was paid to keeping the subject in absolute repose or to controlling the influence of food; nevertheless, it was clearly established that the energy metabolism of the growing child is not only greater, weight for weight, than that of the adult, but that it varies markedly with the age of the child.

Among the outstanding studies of the next fifteen years are those of Benedict and Talbot, who established a respiration laboratory at the Massachusetts General Hospital and pursued with great zeal the investigation of newborn infants, their subjects finally numbering 105, varying in age from 43 minutes to 8 days.[1] They essayed to measure the basal metabolism and for this purpose used in a respiration chamber a wire crib supported at one end upon a stout spiral spring and at the other upon a knife edge, so that every movement of the child could be detected and recorded.

[1] Benedict, F. G., and Talbot, F. B. *The Gaseous Metabolism of Infants with Special Reference to Its Relation to Pulse-rate and Muscular Activity.* Carnegie Institution of Washington, Publication No. 201 (1914). Also Benedict, F. G., and Talbot, F. B. *The Physiology of the New-born Infant; Character and Amount of the Katabolism.* Carnegie Institution of Washington, Publication No. 233 (1915).

In order to study children of various ages Benedict and Talbot subsequently transferred their respiration apparatus to the New England Home for Little Wanderers, and in 1921 contributed a splendid survey of the basal metabolism from birth to puberty, which included, all told, 108 boys and 70 girls from birth to the age of fifteen years.[1]

A little later, at the Carnegie Nutrition Laboratory, Benedict used a respiration chamber large enough to accommodate cots for a dozen subjects at once. In this study over 100 girl scouts from 12 to 17 years in age participated. Girls of the same age were taken together, 10 to 12 of them sleeping in the chamber throughout the night. Information as to muscular activity was secured by connecting the springs of the beds with accurate devices for recording any movement. The girls arrived at the nutrition laboratory about 5:30 in the evening, had a simple supper at 6:00, and were entertained till bedtime by motion pictures showing the work of the laboratory. The metabolism of the group was determined sometime between 1:30 and 5:00 A. M. while all were sound asleep. This is the only extensive study of the sleeping metabolism of girls of these ages.

The introduction of the Benedict portable respiration apparatus in 1918 greatly facilitated the study of the basal energy metabolism, its low cost making it available to many laboratories in which a respiration calorimeter would have been an unattainable luxury. At the University of Chicago, under the leadership of Dr. Katherine Blunt (now President of the Connecticut College for Women), studies with this apparatus were made on many children from the University Elementary School, one of the most important being on 96 normal children who came for their tests in the latter part of the morning instead of before breakfast, their parents having agreed to give them a light and early breakfast, with no meat, eggs, or coffee to cause any special stimulation of metabolism, and they having pledged themselves to eat

[1] Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty*. Carnegie Institution of Washington, Publication No. 302 (1921).

nothing between this breakfast and the test. Preliminary experiments had shown that the effect of this small breakfast would be negligible after an interval of four hours.

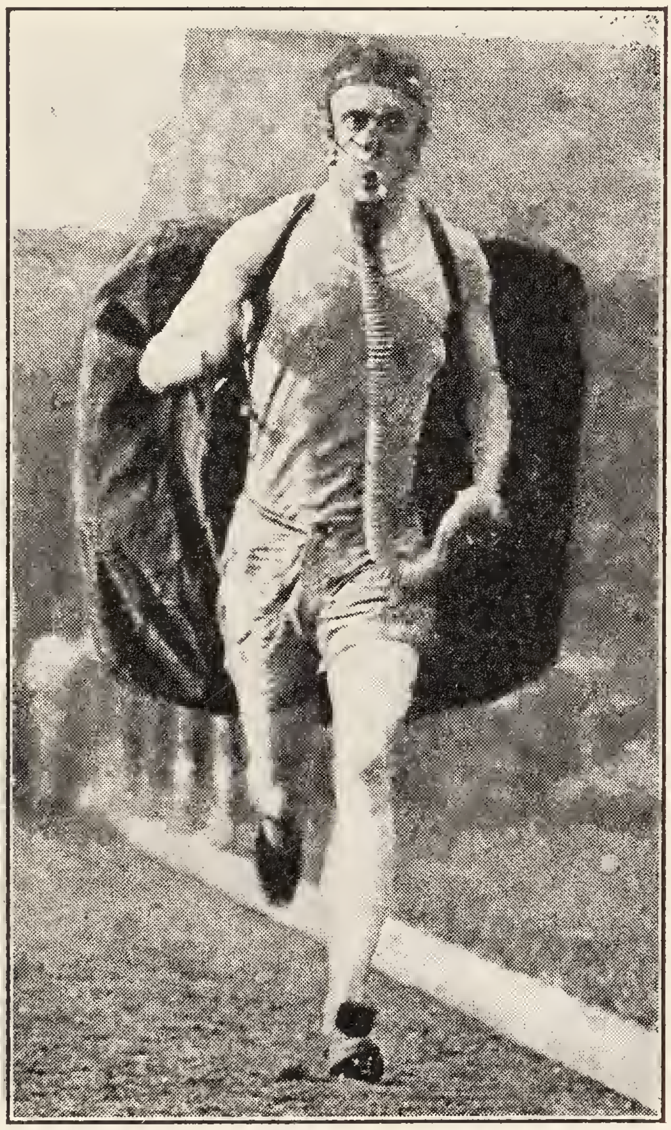
In 1924 Professor Grace MacLeod of Teachers College, Columbia University, tested 43 girls from 11 to 14 years of age from the Horace Mann School of Teachers College. The girls came without breakfast and after their test had a "breakfast party" in a kitchenette adjacent to the laboratory. This they enjoyed very much and it enabled them to report for their classes no later than 9:30 A. M. Fifteen of these subjects were followed through two or three years, and the whole series represents more data for these ages than any other work.

The first studies of the basal metabolism of the nursery school child by means of the Benedict respiration apparatus were made by MacLeod and Robb in 1934.[1] Twenty-nine children, 12 boys and 17 girls, all between the ages of three and four years, were included. The children were familiarized with the mouth-piece and nose-clip used with the Benedict respiration apparatus by playing games in which they could run about with these amusing appliances on their faces and then were trained to keep quiet with them on while being told a story. "A child was judged ready for a basal metabolism test when, during a preliminary play period, he would lie still with mouth-piece and nose-clip adjusted, listening to a story for at least five minutes." During the test one adult sat by the child, telling him a story while a second person manipulated the apparatus.

To measure the energy cost of various forms of free activity another method of study has frequently been adopted. This is the use of the Douglas bag, which is made of rubber, gas tight, so as to hold any desired amount of oxygen. When the apparatus is filled the subject is connected to it by means of a face mask and breathes the oxygen-rich air from the bag. At the end of the period, the air in the bag is analyzed,

[1] Robb, E. "The Energy Requirement of Normal Three- and Four-Year-Old Children." *Dissertation* Columbia University (1934).

and the amount of oxygen left and of carbon dioxide collected are determined. Miss E. M. Bedale, in 1922, used this apparatus to determine the energy cost of school life in a private school in Hampshire, England, 45 boys and 55 girls, 8 to 18 years of age, serving as subjects. Among the occupations studied were all the typical activities of a school child's day, from a cold bath in the morning, through the work of classroom and laboratory, the sports of the afternoon, tea, and evening classes, and finally going to bed.



(*Courtesy of the New York* Times)

Fig. 23.—Using the Douglas Bag to Determine Energy Expended in Running.

For studies of energy expenditure under a variety of conditions, a respiration chamber is most accurate and convenient. With such a chamber, MacLeod and her associates have made several studies of the cost of activity in children. In an investigation with Robb already referred to, the energy output during quiet play was compared with the basal metabolism. Three children were taken into the chamber at a time by an adult who remained with them, sitting quietly at one side, during a half-hour period. The children were well contented with the ordinary playthings of the nursery school—blocks, trains, balls, marbles, tinker toys, etc.—and within the confines of the chamber were easily kept from too great boisterousness.

In studies with Potgieter,[1] six girls between 9 and 10 years

[1] Potgieter, M. "The Energy Cost of Physical Activity of Nine-Year-Old Girls." *Dissertation*, Columbia University (1933).

of age, living in a home for children with broken homes, found it a diversion to come in pairs after school to spend an hour in the chamber. During periods of quiet play they engaged in drawing or painting or cutting paper dolls. Their form of activity was stair-climbing. In turn they ascended and descended a specially built staircase of four steps, keeping time to a metronome.

(*Courtesy of Dr. C. M. Taylor*)

FIG. 24.—Ten-Year-Old Boys in the Respiration Chamber.

One is pedaling on the bicycle ergometer; the other is sitting at quiet play awaiting his turn to ride.

In studies with Taylor,[1] a bicycle ergometer was used to investigate the cost of activity and mechanical efficiency of six boys approximately nine years of age. They went into the chamber in pairs, one sitting at quiet play while his team mate pedaled on the bicycle. Red and green lights helped the cycler to maintain an even speed, red flashing on when he went too fast and green when he slackened his paces. In studies with Williams [2] on the influence of sleep on the energy metabolism of nursery school children tests were made on four three- and four-year-old children during their regular afternoon nap, which was taken in the respiration chamber immediately after their midday meal. Upon waking, tests with the Benedict student respiration

[1] Taylor, C. M. "The Energy Metabolism and Mechanical Efficiency of Young Boys." *Dissertation*, Columbia University (1937).

[2] Williams, D. E. "The Influence of Sleep on the Energy Metabolism of Three- and Four-Year-Old Children." *Dissertation*, Columbia University (1934).

apparatus were made, each child still lying on his cot in the chamber.

The introduction of the oxy-calorimeter in 1925 facilitated a type of study most useful in learning children's total energy requirements. This is the dietary study. Accurate account of the food consumed over a sufficiently long period and careful records of the child's changes in weight are essential. The energy value of the food can be determined by drying a whole meal or a whole day's ration and burning a sample in the oxy-calorimeter. If growth is normal, the calories eaten must have been sufficient to compensate for the energy expenditure and storage of energy-yielding materials in growth. Professor Lydia J. Roberts, head of the Home Economics Department of the University of Chicago and her pupils have applied this method in a study of 35 boys doing farm work in comparison with 34 boys engaged in the ordinary activities of school life, and also in one of 52 girls from 10 to 16 years of age, mostly living in well managed institutions.[1]

An extended study of the food consumption of girls 6 to 13 years old was conducted by Dr. Martha Koehne and Miss Elsie Morell [2] at University Hospital, Ann Arbor, Michigan. Quantitative records were kept for 28 cases, 11 of whom were under observation for from 91 to 192 days and only 3 for less than 40 days. The menus were standardized—one for each day of the week—to simplify work in the kitchens where all of the food was accurately measured or weighed. The portions eaten by each child were also weighed. The weight of first portions was always adjusted to the size and appetite of the child, as well as possible, but additional weighed portions were served on request. The children were weighed once a week and measured once a month and the nutritive value of each diet was calculated from average

[1] Wait, B., and Roberts, L. J. "Studies in the Food Requirement of Adolescent Girls, I. The Intake of Well Nourished Girls." *Journal of the American Dietetic Association*, Vol. 8, page 209 (1932).

[2] Koehne, M., and Morell, E. "Food Requirement of Girls from Six to Thirteen Years of Age." *American Journal of Diseases of Children*, Vol. 47, page 548 (1934).

analyses. During the course of these investigations, 35 balance studies for periods of one week each furnished evidence that the estimations of food intake were reasonably accurate.

Although there are still many ages at which the number of cases is far too few, we can now discuss, with the satisfaction which comes from accurate experimental data, the four quotas which make up the total energy requirement of the growing child: (1) The basal metabolism; (2) The expenditure due to the influence of food; (3) The influence of muscular activity, and (4) The storage of energy-bearing materials in the process of growth.

The Basal Metabolism

Any study of the basal metabolism of the human infant must be made during sleep and not more than three or four hours after a meal, because there is no way of keeping a baby perfectly quiet when awake or hungry. It is therefore impossible to make studies of the basal metabolism of infants on exactly the same basis as those of older children and adults. The food raises the metabolism, the sleep may lower it. Probably the actual figures obtained are somewhat higher than true basal values.

Basal Metabolism and Surface Area

During the first week of life the baby's basal metabolism, estimated on the basis of calories per square meter of body surface, is at least one third lower than that of the adult and very much lower than that of older infants and children, averaging 20 to 24 calories per square meter per hour. This low heat production is attributable to the low muscle tonus of the newborn. A similar condition exists in the premature infant, whose heat production is still lower.

By the end of the first two weeks the sleeping metabolism of the baby will have risen to approximately adult level, but it does not stop there; instead it keeps on rising rapidly until the end of the first year or early part of the second, when it reaches the highest point in the normal life of the

individual. Thereafter, it declines, the rate varying with age until the adult level is reached, as shown in Fig. 25.

It will be observed that at first the fall is rather rapid for two or three years and then becomes more gradual. Just before puberty, in both boys and girls, there is a period in which the metabolism is increased for awhile. DuBois in 1916 determined the basal metabolism of eight boy scouts at the ages of 12 to 14 years and found it to be 25 per cent above the adult level on the basis of surface area. Three

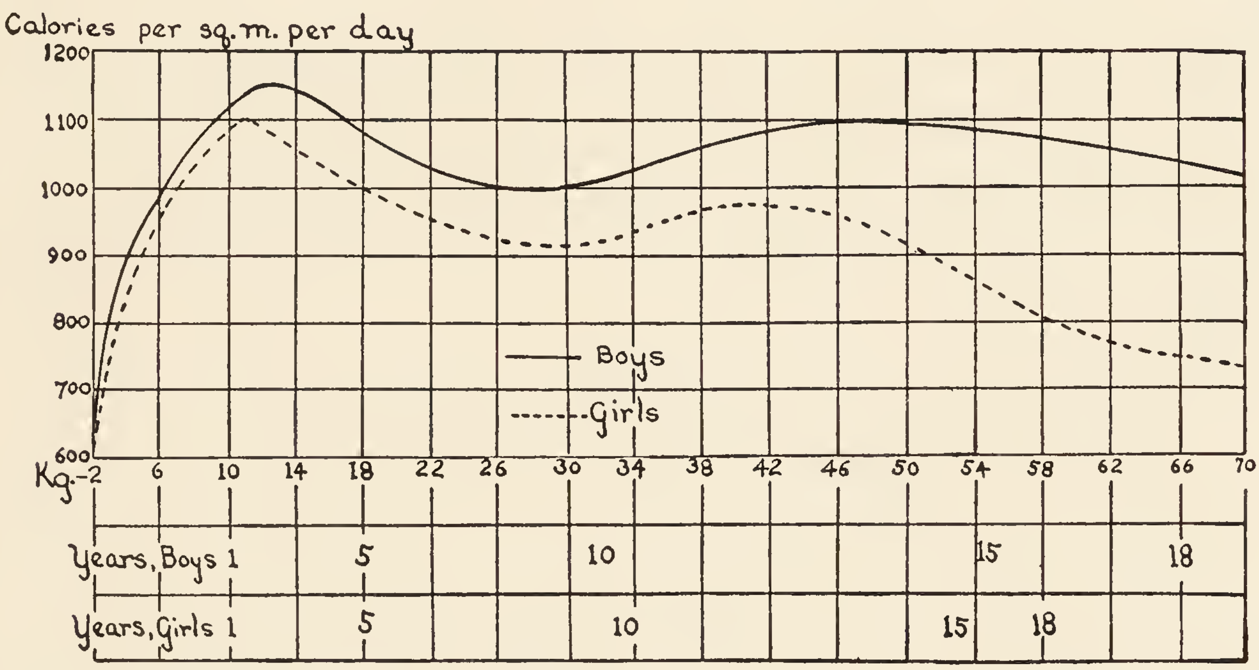


FIG. 25.—Basal Metabolism from Birth to 18 Years in Calories per Square Meter per Day.

of the boys showed no sign of approaching puberty, five gave more or less definite signs. Two years later (1918), when puberty was established in every case, the boys had an average increase in weight of 46 per cent and in height of 10 per cent but the basal metabolism had dropped rather sharply and was, on the basis of surface area, 13 per cent less than before, but still about 11 per cent higher than the adult level.

In the study of 43 girls between 11 and 14 years of age made by MacLeod, there was evidence of an increased rate of metabolism corresponding to that in the investigation by DuBois. The influence of puberty on the basal metabolism can be determined only by following the same individual through several years, since puberty comes at different

CHANGES IN BASAL METABOLISM OF BOYS WITH AGE

Subject	Age in 1916	Signs of Puberty 1916	Signs of Puberty 1918	Weight 1916 Kg.	Increase in Weight in 2 Years Per Cent	Height 1916 Cm.	Increase in Height in 2 Years Per Cent	Cal. per Sq. M. per Hr. 1916	Change in Cal. in 2 Years Per Cent
L. B.	13–3	±	++	28.5	20	141	7	51.6	−14
J. B.	12–6	o	±	30.4	61	141	6	54.4	−19
R. F.	12–8	+	+++	35.4	38	148	12	50.7	−23
F. S.	12–10	o	+	32.1	33	142	10	51.0	−3
A. A.	13–8	o	+	30.6	29	147	19	49.9	−10
H. B.	13–10	++	+++	36.6	34	146	11	47.4	−9
H. K.	13–11	±	++	36.0	37	148	12	48.8	−11
Average				32.8	46	145	10	50.6	−13

times and the increase in the basal metabolism appears to be usually within a range of from 10 to 20 per cent. Any error in the basal determination or any averaging of groups

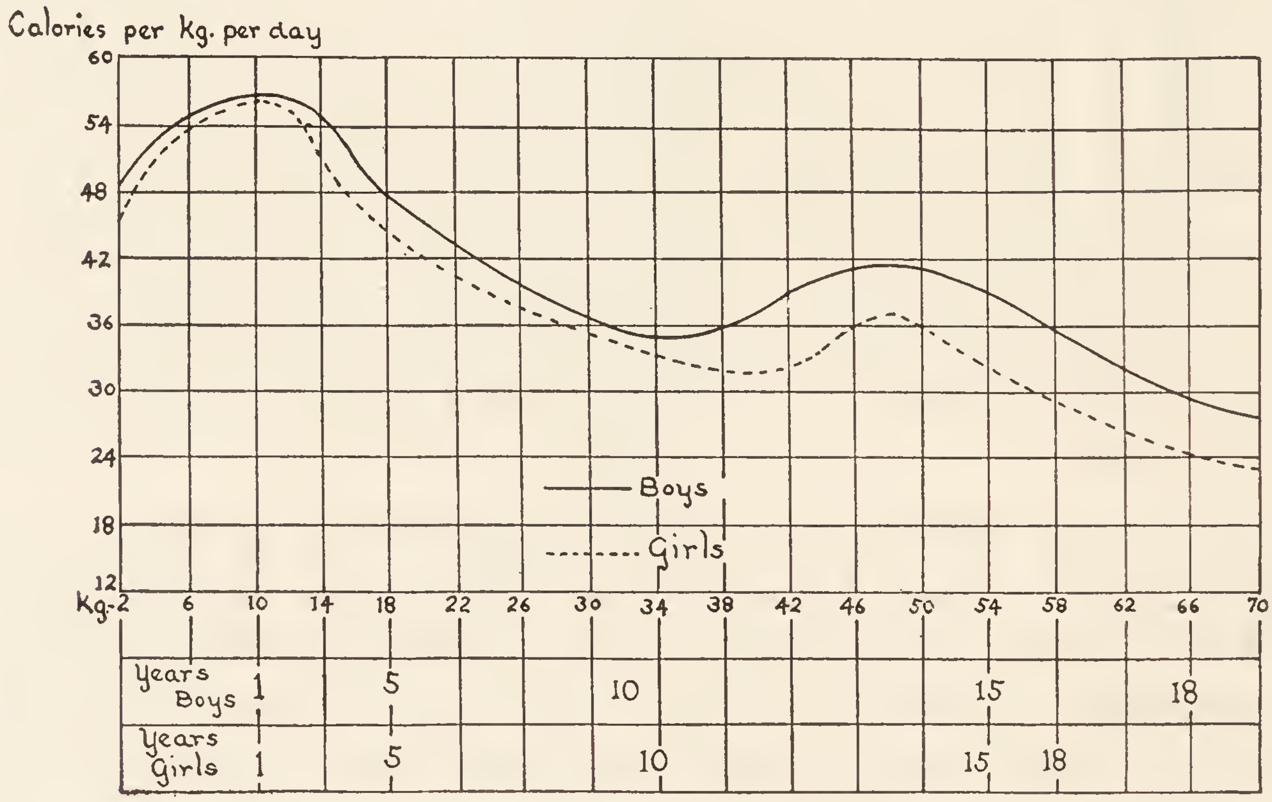


FIG. 26.—Basal Metabolism from Birth to 18 Years in Calories per Kilogram per Day.

either of girls or boys by years is likely to obscure the changes. The general tendency for both boys and girls is indicated in Figs. 25 and 26 and in the table on page 90.

It will be noted also that there is an increasing divergence between the curves for the two sexes as maturity is approached. One of the notable features of that for girls is the rather abrupt drop after the age of fourteen, in contrast

to the continuing high rate for boys. The male organism appears to be more stimulated by the maturing of the sex organs and reaches the adult level considerably later.

Basal Metabolism in Relation to Body Weight

Expression of the basal metabolism in terms of surface area makes it easier to appreciate the changes in energy requirement distinctly attributable to changes in age, but for practical everyday life, in which we measure body weight rather than surface area, it may be helpful to consider the basal metabolism at different ages in terms of body weight. Consideration of what has already been said with regard to the relationship between size, shape, and surface area would lead us to expect that the basal metabolism of the child in terms of calories per kilogram would be greater than that of the adult. The average infant at birth has about one seventh the surface area of the adult man, but only one twentieth his weight. Comparison of an actual study of an infant six months old, weighing 6.09 kilograms and having a surface area of 0.339 square meter, with an average adult having a surface area of 1.81 square meters will show the difference in results when the daily energy output is calculated both to surface and to weight.

An Infant's Basal Metabolism Compared with an Adult's

	Infant Calories	Adult Calories
Total basal metabolism for 24 hours	312	1,700
Calories per square meter per hour	38.3	39.5
Calories per kilogram per hour	2.1	1.0

Here it appears, as already stated, that on the basis of surface this young child's metabolism is very close to that of the adult, but on the basis of body weight it is more than twice as great. As the child grows larger, the metabolism in terms of body weight as well as in terms of body surface gradually falls. Thus in a continuous study of the same little girl from the age of five months to three years and five months the following changes occurred:

Changes in a Child's Basal Metabolism with Age

Age	Weight Kg.	Basal Energy Expenditure		
		Total Cal. per Day	Cal. per Sq. M. per Hr.	Cal. per Kg. per Hr.
5 mos.	5.3	317	43.4	2.5
10 mos. 1 wk.	9.2	474	42.6	2.2
1 yr. 1 mo.	11.3	564	42.8	2.1
1 yr. 5 mos.	13.4	600	40.3	1.9
1 yr. 9 mos.	15.1	633	39.5	1.8
3 yrs.	16.9	667	40.9	1.7
3 yrs. 5 mos.	17.5	660	39.2	1.6

Here the tendency of the basal metabolism to fall with increasing years, whether it is expressed in terms of surface or of weight, is clearly shown in the case of a single individual.

The following table gives typical figures for basal metabo-

Basal Energy Metabolism of Children from Birth to 18 Years

Age	Calories per Square Meter per Hour		Calories per Kilogram per Day		Calories per Pound per Day	
	Boys	Girls	Boys	Girls	Boys	Girls
Premature infants	25	25				
Birth to 2 weeks	25.5–29.2	25.5–29.2				
3 months			53	53	24	24
6 months			54	54	24	24
9 months			55	55	25	25
1 year	47.5	46.2	56	56	25	25
2 years	47.9	45.4	56	55	25	25
3 years	47.1	43.3	51	48	23	22
4 years	45.8	42.5	47	44	21	20
5 years	44.5	41.6	45	42	20	19
6 years	43.7	41.2	43	40	20	18
7 years	42.9	40.4	41	39	19	18
8 years	42.1	40.0	40	38	18	17
9 years	41.6	39.5	38	37	17	17
10 years	40.8	37.1	37	36	17	16
11 years	38.9–48.0	37.5–41.5	35	34	16	15
12 years	38.5–51.5	38.2–44.3	34	32 [b]	15	15
13 years	38.5–49.7	37.4–42.0	40 [a]	31 [b]	18	14
14 years	36.2–44.3	36.6–42.3	41 [a]	37 [b]	19	17
15 years	41.2–45.3	31.0–37.8	36 [a]	25	16	11
16 years	41.0–44.7	31.0–36.1	33	23	15	10
17 years	41.0–43.7	31.0–34.8	30	22	14	10
18 years	40.9–42.9	32.3–37.1	30	20	14	9

[a] Gillett, L. G. *Food Allowances for Healthy Children*, page 16. New York Association for Improving the Condition of the Poor (1917).

[b] MacLeod, Grace. *Studies of the Normal Basal Energy Requirement*, page 34. Dissertation, Columbia University (1924).

lism from birth to maturity, both in terms of surface area and of weight:

The Influence of Food

We have seen, in studying the energy requirements of adults, that out of every 100 calories eaten toll must be taken for the heat wasted in the process of distributing the fuel foodstuffs to the cells; a loss which varies with the nature of the diet, but is not likely in ordinary life to exceed 6 per cent of the total calorie intake. We have as yet very little exact information in regard to the stimulating influence on metabolism of food during growth, but we know that food which is stored in the process does not stimulate metabolism.

The Influence of Activity

In the child, as in the adult, muscular activity increases energy expenditure in proportion to its severity. It is difficult, however, to standardize the activities of infants and children, and not enough work has been done in this field to permit definite statements as to the cost of different kinds of children's activity.

The most extensive studies have been made on babies. Benedict and Talbot have observed instances in which a baby's metabolism was raised as much as 200 per cent above the basal level by vigorous crying, but few babies can cry as hard as that. An average baby is not likely to exceed his basal output by more than 65 per cent and that only for a short time. Murlin has also made many studies of the influence of activity in young babies and estimates that the extra expenditure in crying is proportional to the time spent; that is, crying 1 per cent of the time raises the metabolism 1 per cent. For an infant who cries no more than the average normal infant, he considers an allowance of 30 per cent sufficient, while for an infant crying "most of the time" 40 per cent might be allowed.

Benedict and Talbot studied two infants, one aged two

months, three weeks and the other six months, one week, throughout the twenty-four hours and found that while they might increase the metabolism 60 or 70 per cent for short periods, the average increase for the day was about 25 per cent above basal. For older infants, not confined to the crib, an allowance of 30 to 40 per cent above basal seems to be necessary.

The activities of older children have not as yet been made the subject of much investigation. Sondén and Tigerstedt's studies of groups of school children sitting in the respiration chamber (page 80) give evidence that the calorie output of boys in the schoolroom may be 75 per cent above basal, that of girls more nearly 50 per cent. In Bedale's study in Hampshire, England, twenty-five separate school occupations were studied, each child wearing a Douglas bag during any period of activity. The increases over the basal metabolism of some of the activities were as follows:

Increase over Basal Metabolism in Different Activities

Activities	Per Cent of Basal
Piano practice	56
Standing	80
Dressing	170
Cricket	259
Gymnastics	298
Gardening	305
Cold bath	503
Dancing	547
Swimming	669
Football	762

In the studies made by MacLeod and her co-workers, the saving in sleep of children three and four years old as investigated by Williams averaged about 16 per cent of the basal metabolism. The influence of the children's noonday meal taken just before going into the chamber for their nap was found to balance the saving in sleep. The quiet play of children three and four years old, as observed by Robb, produced an increase in metabolism over the basal level which averaged 66 per cent for girls and 69 per cent for

boys; the quiet play of nine- and ten-year-old girls, as directed by Potgieter, resulted in an increase of 90 per cent; and that of boys nine to eleven years old, limited very strictly to finger movements such as disengaging of metal rings, was brought in Taylor's investigation to the low figure of 53 per cent. The nine- and ten-year-old girls, climbing a small staircase at a rate set by a metronome, raised their energy output 292 per cent; and the boys of similar age, pedaling on the bicycle ergometer, raised their output 290 per cent. These studies indicate quite clearly that the cost of activity in children tends to parallel their basal metabolism, which means, of course, the younger the child the greater the energy expenditure per unit of weight in any given type of activity. Thus quiet play in case of the nursery

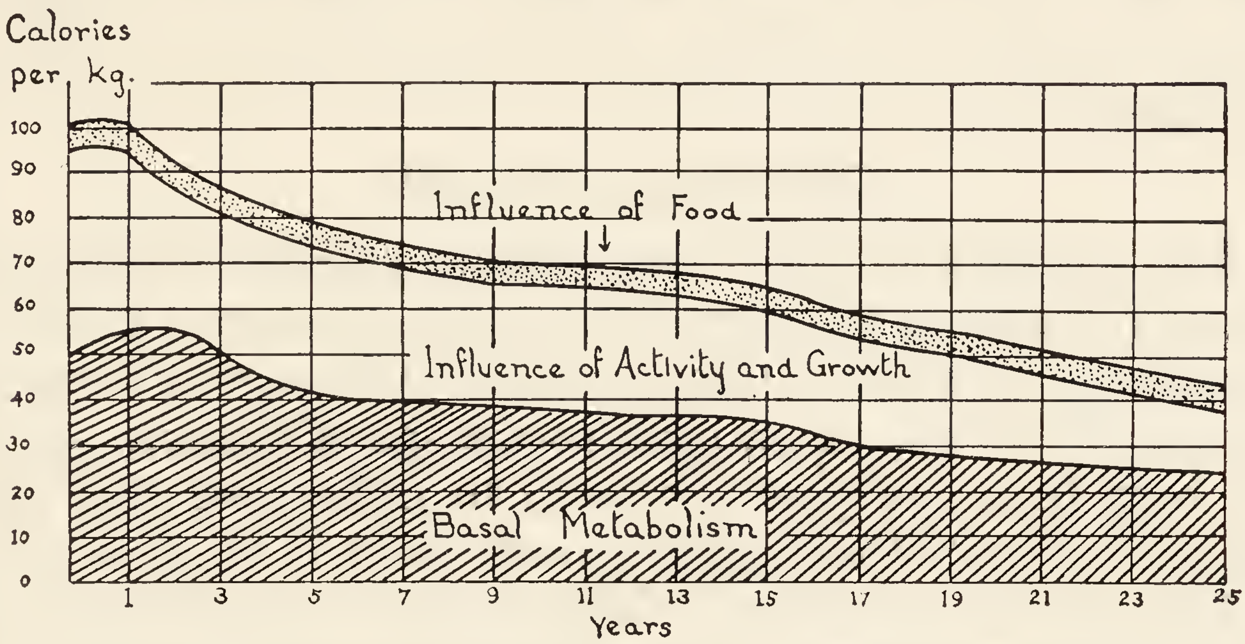


FIG. 27.—Changes in Energy Requirements of Children with Age.

school children resulted in an energy output of 3.8 calories per kilogram per hour, while in an adult an activity judged to involve about the same amount of muscular work, namely dressing and undressing a doll of the size of a human infant, cost the adult only 1.76 calories per kilogram per hour. In both cases the calories spent in activity were about 70 per cent of the basal metabolism. Stating it another way, quiet play cost the nursery school child as much per unit of weight as walking rapidly for the same time would cost an adult. Gillett, in setting dietary standards for children, has sug-

gested that the total energy requirement is at least double the basal metabolism and this has been confirmed by Dr. Chi Che Wang and her associates working under the Children's Hospital Research Foundation at the University of Cincinnati with regard to girls between 12 and 15 years of age. Twenty-two of them lived for two weeks in the metabolism ward, going out to school and returning for meals and the night's rest. Their food was weighed and samples analyzed. It was found that their basal metabolism accounted for fully half the total calories represented in their food.[1] Such an allowance, while sufficient for children whose activities may be classed as light work, would not be sufficient for those who are more active. For boys, especially between 11 and 15 years of age, an allowance of three times the basal metabolism seems desirable. This is what Bedale found English school children, both boys and girls, commonly spending.

The Influence of Growth

The proportion of the total calories ingested which will be used for growth will vary directly with the rates of growth. The charts in Section 2, Chapter XXIV, showing the average annual rate of gain from birth to the age of eighteen years for both boys and girls will serve to make clear that the periods of greatest storage in growth occur in the first year of life and again between the ages of twelve and sixteen, the sixteenth year in boys and the thirteenth year in girls generally being the time when the rapid growth of adolescence reaches its maximum. In any one of these years from ten to fifteen pounds may be added to the body weight.

Just how many calories are needed for growth at any given time it will always be difficult to say, since the rate of growth varies considerably with the individual; at the present time we have no standard figures for the growth quota, but with the exception of the periods of most rapid growth, 10 to 15 per cent of the basal metabolism probably represents

[1] Wang, C. C., Kaucher, M., and Wing, M. "Metabolism of Adolescent Girls." *American Journal of Diseases of Children*, Vol. 51, page 801 (1936).

the growth requirement fairly well. It must be constantly borne in mind that storage in growth is only possible when the basal energy requirement and the additional calories needed for activity have been met. If there are no calories in excess of these requirements, there can be no growth.

The Influence of Sleep

The complete relaxation of a healthy sleeping child is always impressive, and indicates a decrease in the energy expenditure below the basal metabolism. The amount of this reduction can be determined only by careful testing. Benedict in 1922 studied two newborn babies in the respiration chamber and found their sleeping metabolism 6 and 15 per cent lower than their basal metabolism. A few years later Dr. Chi Che Wang and Miss Ruth Kern studied five boys and seven girls between the ages of four and seven years in the same type of chamber at the Michael Reese Hospital in Chicago. The average saving in sleep was 16 per cent. In 1934 MacLeod and Williams determined the sleeping metabolism of four nursery school children, two boys and two girls between three and four years of age taking their midday nap in the respiration chamber at Teachers College, Columbia University, and then their energy output with the Benedict student apparatus immediately upon waking. The differences between the two ranged from 12 to 23 per cent, showing the great relaxation in the first hour of sleep after a morning of active exercise in the nursery school. As in the case of children's activity, the total saving of calories is much more for a child than an adult, since 2 per cent of the basal metabolism on the adult basis of one calorie per kilogram per hour is only 0.1 of a calorie, while on the nursery child's basal metabolism of two calories per kilogram per hour it would be twice as much.

The Total Energy Requirement of Children

We have now considered separately the four quotas which together constitute the total energy requirement of children, viz.,

1. Basal metabolism
2. Metabolism due to influence of food
3. Metabolism due to influence of activity
4. Storage of energy-yielding material in growth

The changes in the total daily requirement as influenced by each of these quotas is roughly indicated in Fig. 27.

Since basal metabolism and activity are relatively greater than in the adult and there is an additional requirement for

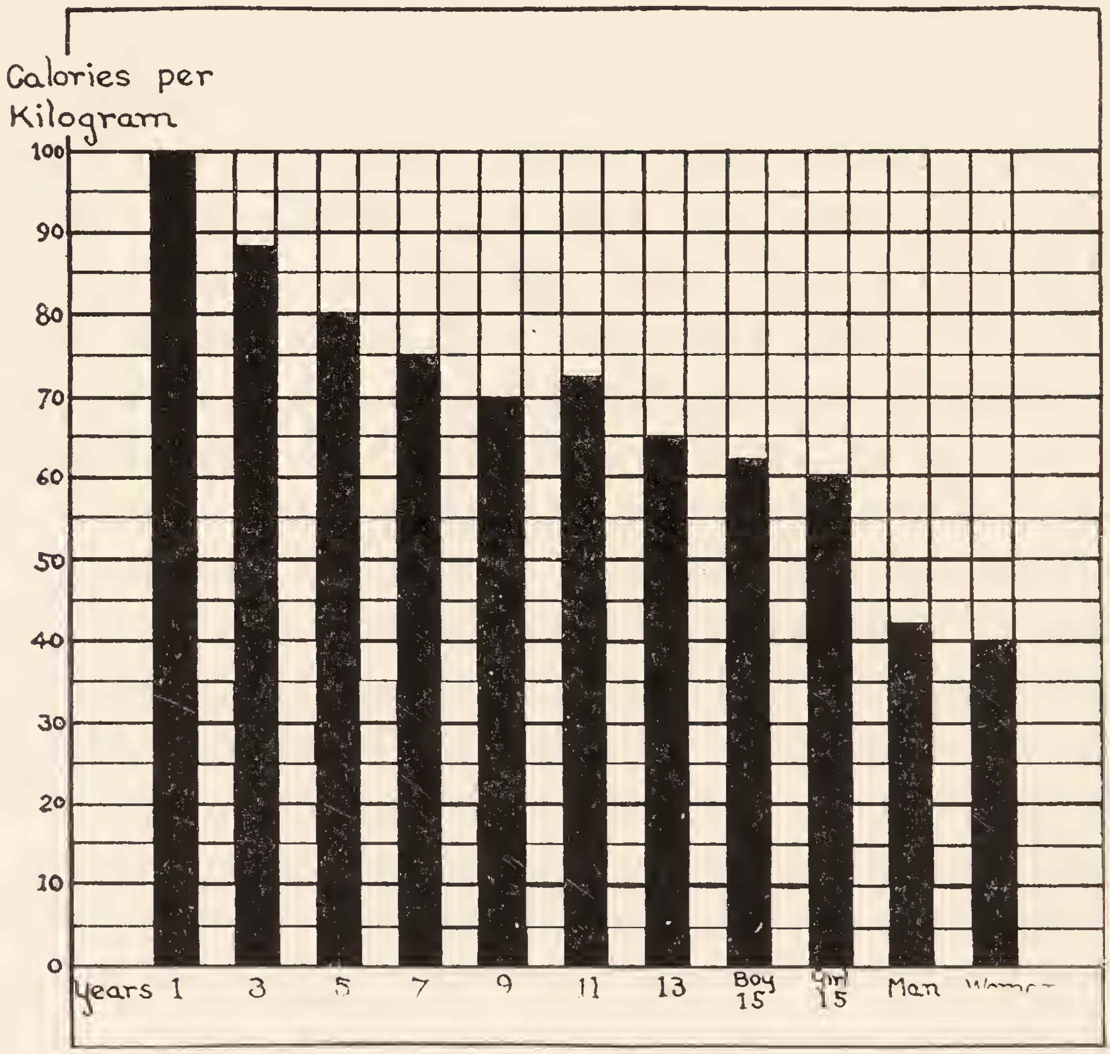


FIG. 28.—Total Daily Energy Requirement of Children Compared with a Moderately Active Man and Woman on the Basis of Calories per Kilogram per Day.

growth, it is plain that children's total food needs will be considerably higher than those of adults in proportion to body weight. The difference between children and their parents is depicted in Fig. 28, in which the figures for the father and the mother are the averages for moderately active persons.

Our most reliable information as to the total energy requirement of children has come from studies of the actual

food consumption of healthy children. Roberts [1] has estimated from the available data the energy needs of the first year as follows:

TOTAL DAILY ENERGY NEEDS OF INFANTS BY MONTHS

Age Months	Calories per Day
1	500
2	610
3	675
4	720
5	760
6	795
7	820
8	860
9	880
10	900
11	940
12	1,000

In terms of body weight they are approximately as follows:

ENERGY NEEDS OF INFANTS IN TERMS OF BODY WEIGHT

Age	Total Calories per Kg.	Total Calories per Lb.
First three months	100–105	45–48
Second three months	95–100	43–45
Third three months	90–95	41–43
Fourth three months	85–95	39–43

In 1917 the New York Association for Improving the Condition of the Poor, feeling the need in its extensive welfare work for adequate standards by which to compute the food requirement of the family, arranged for a systematic survey and digest of all the available data relating to food requirements of children. This was made by Miss Lucy Gillett, Director of Nutrition for the Association, and included 563 experiments in all, covering the period from 1878 to 1917. From this was formulated the first American standard for total energy requirements of children.

In 1932, Roberts, from the published data and her own unpublished figures, proposed new standards for girls from 2 to 17 years of age. All workers have observed less con-

[1] White House Conference on Child Health and Protection. *Growth and Development of the Child*, Part III, "Nutrition," page 392. The Century Co. (1932).

formity to type in case of girls, which makes prediction of the energy requirement difficult. Neither age nor weight is a very satisfactory basis. Both Benedict and MacLeod found a closer correlation with height, and this has been confirmed by Roberts, who finds calories per inch quite reliable. For moderately active girls 6 to 16 years she recommends 39 to 40 calories per inch of height and before and after these years, 36 to 37 calories per inch of height. Very active children will probably have requirements above these estimates.

A table which takes into account both height and weight is probably the most satisfactory. Wait and Roberts have made estimates for girls from 10 to 16 years of age as follows:

Total Daily Energy Requirements of Girls According to Height

Height in Inches	Calories per Kg.	Calories per Lb.
47–49	75	34
49–53	70	32
53–55	65	30
55–57	60	27
57–59	55	25
59–61	50	23
61–63	45	20
63–67	40	18

Thus a girl 52 inches tall will have an estimated requirement of 70 calories per kilogram or 32 calories per pound. If she weighs 64 pounds her total requirement for the day will be 2,048 calories.

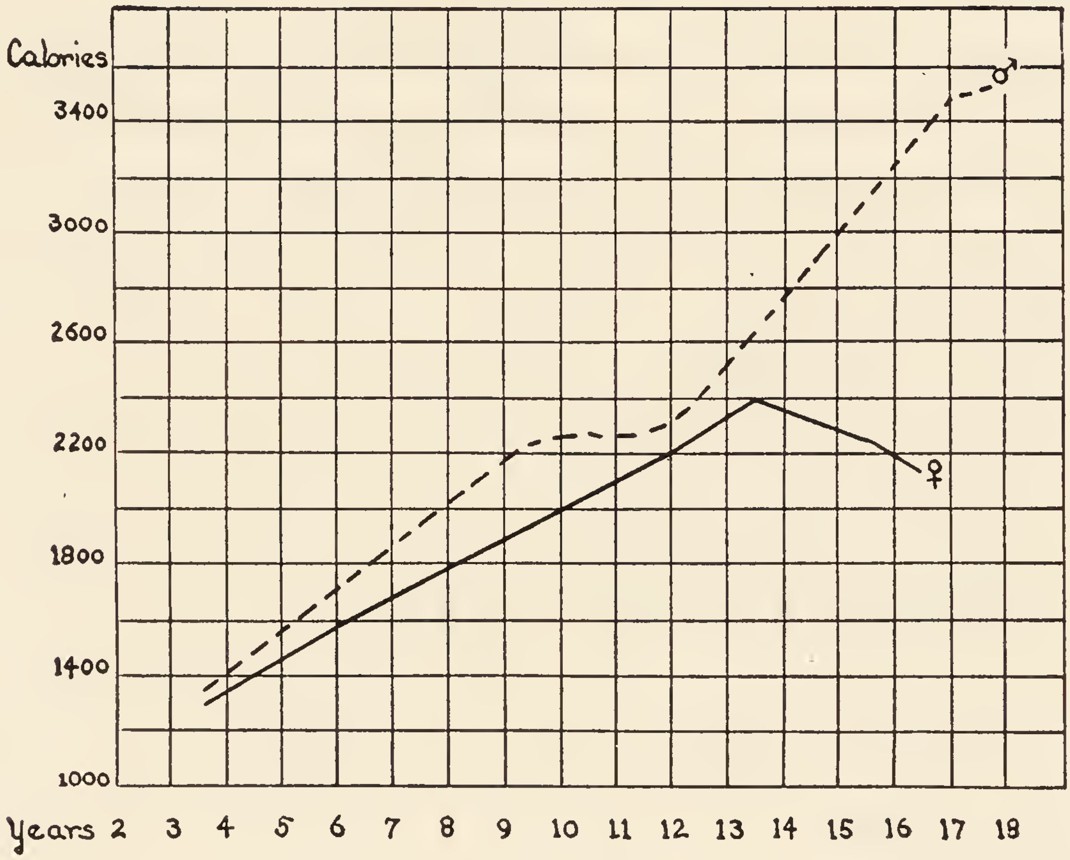
Boys eat more on the average at any age than girls, and this difference is markedly increased after 13 years. Their calories per inch increase with age, from 35 at two years to 55 at 17 years. In many dietary studies the food consumption of the boys was probably limited by the supplies available rather than by their capacity.

Roberts has collected all available data on the total energy requirement of children and plotted curves for both boys and girls which represent the average intake per day at different ages. These curves are reproduced in Fig. 29.

Changes in the feeding of boys are illustrated by the history

of Christ's Hospital, that famous English school established by Edward VI in 1553. Records of the diet and the physical development of the boys have recently been made available by the Chief Medical Officer of the school.[1]

An existing diet sheet for the week ending August 12, 1704, shows that the boys, 9 to 18 years old, received only 1,170



(*After Roberts*)

FIG. 29.—Total Daily Energy Intake of Normal Boys and Girls.

calories in solid food (mostly bread, with cheese and a little butter) and an estimated 730 calories in crude, home brewed beer. Charles Lamb, who attended the school from 1782 to 1789, bears touching testimony in his *Essays of Elia* to the miserable quality as well as quantitative inadequacy of the dietary régime of that period when, as Drummond aptly says, "Food restriction in both quantity and quality was widely regarded as one of the disciplines to which the child was subjected for the good of its soul." [2]

Knowledge of the food requirements of mankind was greatly needed. The Governors of the school little knew

[1] Friend, G. E. *The Schoolboy. A Study of His Nutrition, Physical Development and Health.* W. Heffer and Sons, Cambridge, England (1935).

[2] Drummond, J. C. *Lane Medical Lectures: Biochemical Studies of Nutrition Problems,* p. 17. Stanford University Press (1934).

how near the truth they came when they forbade vendors of any sort to sell "anything eatable or drinkable" to the schoolboys in saying, "This tends not only to the prejudice of the children's health but is also a disreputation and scandall to the House, it looking as if the children wanted victuals." But in Lamb's time Lavoisier had begun his classic work and had noted the tragic irony of the poor worker, who spends the most calories at his labor, having the least money to buy them. In 1834 the diet of Christ's Hospital was improved, potatoes being given four days a week instead of two, but the fat was reduced 10 grams, so that the net result was a loss of 81 calories. In 1914 careful records of the physical development of the boys and of the dietary were started. The war years necessitated restrictions which greatly affected the health of the boys but from 1922 to the present there has been steady improvement, the calorie intake being increased from 2,646 in 1913, when beer was discarded, to 2,830 in 1922 and finally to 3,014 in 1933. These values are exclusive of food purchased by the boys in the school tuck shop. In 1919–20 boys approximating 15 years of age had an average weight of 103.3 pounds and an average height of 69.2 inches. In 1928–29 their weight had increased on the average 10 pounds and their height more than an inch, while the smaller boys showed similar improvement. The most marked changes in the dietary were an increase in fat, with butter instead of oleomargarine, and an increase in milk of from half a pint in 1922 to nearly a full pint in 1933.

When account is taken of the basal metabolism of children through the years of rapid growth, their almost ceaseless activity when awake, involving the expenditure of more calories per unit of weight than similar activities in adults, and the necessity of energy-yielding materials to be stored in the process of growth, it is easy to see why children of all ages need a liberal energy supply. The following table will be useful in making a tentative estimate of their energy needs, although only watching their growth rate will tell

whether the estimate has closely approximated requirement.

TOTAL CALORIES FOR CHILDREN IN TERMS OF BODY WEIGHT

Age Years	Calories per Kilogram		Calories per Pound	
1–2	100–90		45–40	
3–5	90–80		40–36	
6–9	80–70		36–32	
10–13	70–60		32–27	
	Boys	*Girls*	*Boys*	*Girls*
14–15	60–55	50–45	27–25	23–20
16–17	60–55	45–40	27–25	20–18
18–19	55–50	40–35	25–23	18–16

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CHAPTER VI

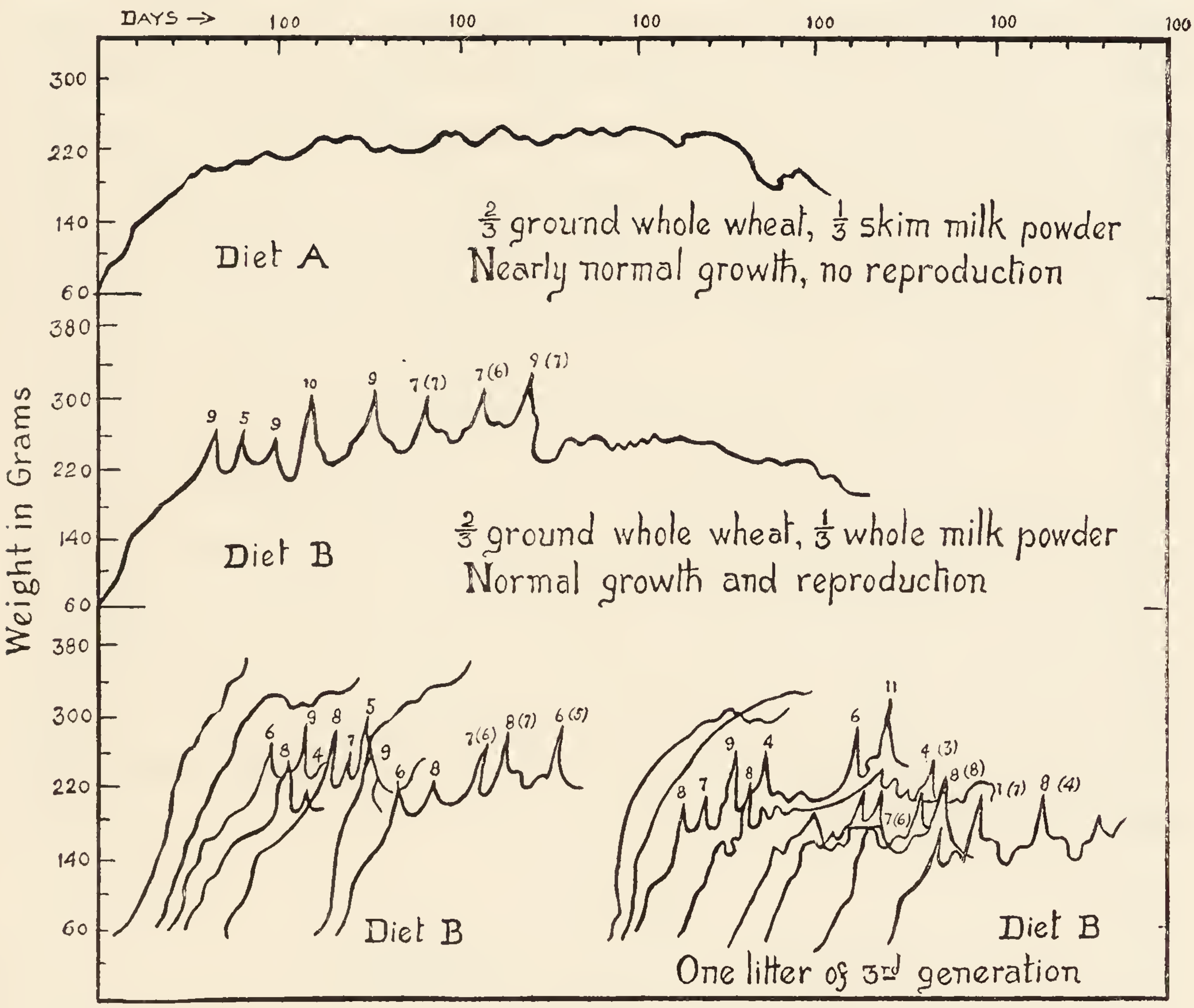
SHORTAGE AND SURPLUS OF CALORIES

The problems of nutrition in the human race at the present time are not primarily problems of keeping alive. Only famines cause the death of any large number from dietary restrictions, and consideration of the way in which great populations like those of India and China have adjusted themselves to rations far from what we now regard as ideal shows enormous capacity for adaptation so far as diet is concerned. We must not, however, consider a diet ideal when it merely maintains life. The best method of demonstrating the difference between a maintenance diet and an optimum one for the individual and the race is by means of experimental animals in nutrition laboratories.

For instance, it is possible for a rat to grow to full adult size and produce offspring which survive and in turn reproduce on a diet consisting of one sixth dried whole milk powder and five sixths ground whole wheat, plus a little common salt. The adults in the first generation of rat families so nourished appear to the casual observer quite like those of another family, nourished on a diet in which the proportions are different, viz., one third whole milk powder and two thirds whole wheat. Only by keeping account of the number of animals born to each mother, the age of maturity, the life span, the rate of growth, and the maximum rate of each individual is any difference in the quality of the two diets detected. The following graph (Fig. 30) shows the growth of two families whose diet differed only in that one had a liberal amount of whole milk while the other had skim milk instead. The family on one third whole milk powder was still prospering in the sixteenth generation; the one on the skim milk diet had no descendants whatsoever.

The Sources of Body Fat

The normal human body has firm, elastic muscles and a moderate store of fat widely distributed over the body, under the skin, around the visceral organs, among the



(*Courtesy of Drs. H. C. Sherman and Florence MacLeod*)

FIG. 30.—Experiments showing how two diets, each capable of bringing well born young to maturity may not be optimum when tested for their value in reproduction and lactation. The first growth curve is the record for over one year of a female rat on a diet of dried skim milk and ground whole wheat. The second shows her twin sister, on a diet in which the skim milk powder was replaced by whole milk powder. The lowest set of curves shows one litter of her descendants in the second generation and one litter in the third generation. Similar records may be pictured for her through 16 generations.

muscle fibers and elsewhere. This fat is advantageous as an insulator, saving the combustion of fuel for the production of heat under stimulus of cold. It also serves as padding for the viscera and the muscles, as support for the eyeball and for the kidneys, protecting against jars and blows, and as a storehouse of energy upon which the body can draw when for any reason food is not immediately forthcoming.

We burn our fuel foods according to the demand of the muscles for energy, not according to the amount eaten. Whatever is eaten in excess of immediate need is stored for future use. Carbohydrate foods (sugar and starch) are stored as glycogen in the liver and to some extent in the muscles; however, the body's capacity to store glycogen being limited, when the glycogen storehouses are full the incoming carbohydrates, if not immediately needed, will be chemically changed and packed away in the still more concentrated form of fat. Fat eaten as such is also stored in the body practically unaltered if not required as fuel at once. Protein, if eaten in large quantity, tends to burn itself off on account of its stimulating effect upon combustion. The well nourished body carries some reserve protein, but has no capacity for storage of any large surplus. In this respect protein differs markedly from carbohydrate and fat.

When a person begins to fast, the reserve glycogen is burned first and is ordinarily exhausted in a day or two. Then fat is drawn upon along with some protein, and the length of time the person can fast without harm is practically determined by his fat reserves.

Section 1

SHORTAGE OF CALORIES

Vigorous human beings carry some reserve of body fat. The best information we have as to the relationship between body weight and health is derived from the data of life insurance companies. These give us the body weight for age and height which has most frequently been found associated with health and longevity. Upon the adult who deviates much in either direction from the so called normal average rests the burden of proof as to whether or not he is as well nourished as he ought to be. The ideal way to settle the matter is to have a complete physical examination. Schools and colleges are increasingly attentive to the desirability of such examinations for students and provide for them through their medical or other health services,

while more and more other health agencies are making such examinations possible for the citizens at large. Any adult can, however, determine by comparison of his own weight with standard weight tables (Tables VII and VIII in the Appendix) whether he is below average weight for age and height and, if so, how much. The best weight for an adult over thirty is now adjudged to be his normal weight for age thirty. Deviations of 15 per cent or less from this in either direction may or may not be significant, but it is advisable to seek the explanation for the deviation, in whichever direction it occurs, and to consider its effect on health and efficiency.

Undernutrition in Adults

It is not desirable for adults to carry too great a store of reserve fuel, as it may become a handicap instead of an advantage. On the other hand, it is possible for the adult to become habituated to living on too low a nutritional level, so that he is unconscious of any disadvantage and will protest that he is "perfectly well," while as a matter of fact he is more liable to both physical and mental fatigue, to nervous diseases, to tuberculosis and other infections, than if he were living on a higher nutritional plane. This is corroborated by investigations made by Blunt and Bauer at the University of Chicago in regard to the basal metabolism and food habits of nineteen underweight college women; eleven of these were found to be eating less than 500 calories a day in excess of their basal metabolism. They confessed that they became tired very easily and yet they were quite certain they were eating enough and could not possibly eat any more. When one of them, who weighed only three fourths as much as she should, was finally induced to increase her food consumption, she admitted that it was very astonishing how much more she could eat and how much better she felt. Very often women even less severely underweight than this one suffer from chronic fatigue to which they have become so accustomed that they are utterly

unaware of how much better they might feel. The combination of a long night's sleep and an increased food intake will often increase vitality surprisingly.

Further evidence of the effect of living on a low nutritional level is furnished by the study made by Benedict and some of his associates on a squad of twelve young men whose habit before the experiment was to consume from 3,200 to 3,600 calories daily. For the first three weeks they were limited to 1,400 calories a day, with a consequent fall in body weight amounting to 12 per cent of their original weight. They were then able to maintain this reduced weight on 1,950 calories daily, and by numerous tests gave evidence that their efficiency in work of various sorts was not measurably impaired. However, they said that they felt less energetic, and had to drive themselves to their tasks instead of undertaking them with abounding energy and a surplus of good spirits. In gymnasium tests they gave out sooner than when living on the higher nutritional level and took less pleasure in their performances. This is in harmony with other studies of undernutrition, which show in various ways that the body tends to conserve its forces when food supplies are insufficient, both by a lowered basal metabolism and by physical inertia.

Undernutrition in Children

There is no simple method of determining a child's nutritional status. There must be well developed muscles with good tone, normally functioning digestive and nervous systems, evidences of a good blood supply, and of skin and mucous membrane in prime condition. Furthermore, there must be assurance that there are ample body reserves of those substances whose storage is known to be favorable to the best development, such as calcium and vitamin A and a certain amount of subcutaneous fat. Growth at a good rate is characteristic of the well nourished child, but true progress can only be determined by weight and height records over considerable periods of time. And it is not

enough that a child carry a certain number of pounds for his height. He may still be flabby and pale, with poor teeth and bad skin, his only nutritional virtue his subcutaneous fat. Weighing and measuring give information of great value if consistently done, month by month and year by year, but they alone will not separate the well nourished from the ill nourished. As Roberts has well said, "An examination into the dietary of the child is an obvious but often overlooked first step in determining the adequacy of nutrition. Though the various requirements are not as yet all defined in precise quantitative terms, the desirable quantities of the various food sources for insuring ample intakes are known; and gross inadequacies in any of these, such as are all too commonly found, may justly be termed malnutrition whether or not outward signs have yet become manifest." [1]

Other points upon which specific information is desirable are the condition of the teeth, the progress of ossification of the bones in relation to age, the amount of hemoglobin and number of red cells in the blood, the state of the appetite, the soundness of sleep, and the general zest for life.

In this chapter we are concerned with undernutrition due to shortage of total calories. Children's energy needs are so high that it is difficult for them to accumulate any reserve of fuel in the form of body fat, and when they do, it is usually used up in the next spurt of growth in height. The body must store in the process of growth materials having energy value and a deficiency of calories only will result in stunting, even if all other dietary essentials are adequately supplied. This can easily be demonstrated by means of laboratory animals. In Fig. 31 is shown a young male rat and its litter brother weaned at the age of four weeks. The upper one was allowed just two thirds as many calories as the lower one, but the two diets furnished both animals with the same amounts of all other dietary essentials. In the nine weeks

[1] Roberts, L. J. *Nutrition Work with Children*, 2nd edition, page 74. University of Chicago Press (1935).

on the restricted diet the one rat made no significant gain in weight although very lively and giving every appearance of being in good health, while the other grew steadily as shown in Fig. 32. When there were added to the restricted ration starch and lard (calories only) to make this diet equivalent to that of the litter mate, the underfed animal doubled its weight in a single week and continued to gain

FIG. 31.—The Effect of Restricting Calories Only Is Shown in These Two Animals. Both are the same age. The upper one had only two thirds as many calories per day as the lower one.

at a rapid rate until it attained the same weight as its brother.

A young child with little adipose tissue is an easy prey to malnutrition, hence it is better for every growing child to be a little overweight rather than underweight for his build. The tables of Woodbury and of Baldwin and Wood (Tables III–VI in the Appendix), derived from the study of thousands of American children, take account of different builds and are helpful in determining whether an effort should be made to increase a child's body reserves of fuel. In estimating the food needs of underweight one should make allowances on the basis of height, according to the table on page 98 or for underweight members of either sex use the

average weight for height and type rather than actual weight. The less easily a child fattens, the greater the need to feed him liberally so that sufficient calories may always be available to sustain any spurt of growth.

The number of children given annual physical examinations is rapidly increasing and it is to be hoped the time

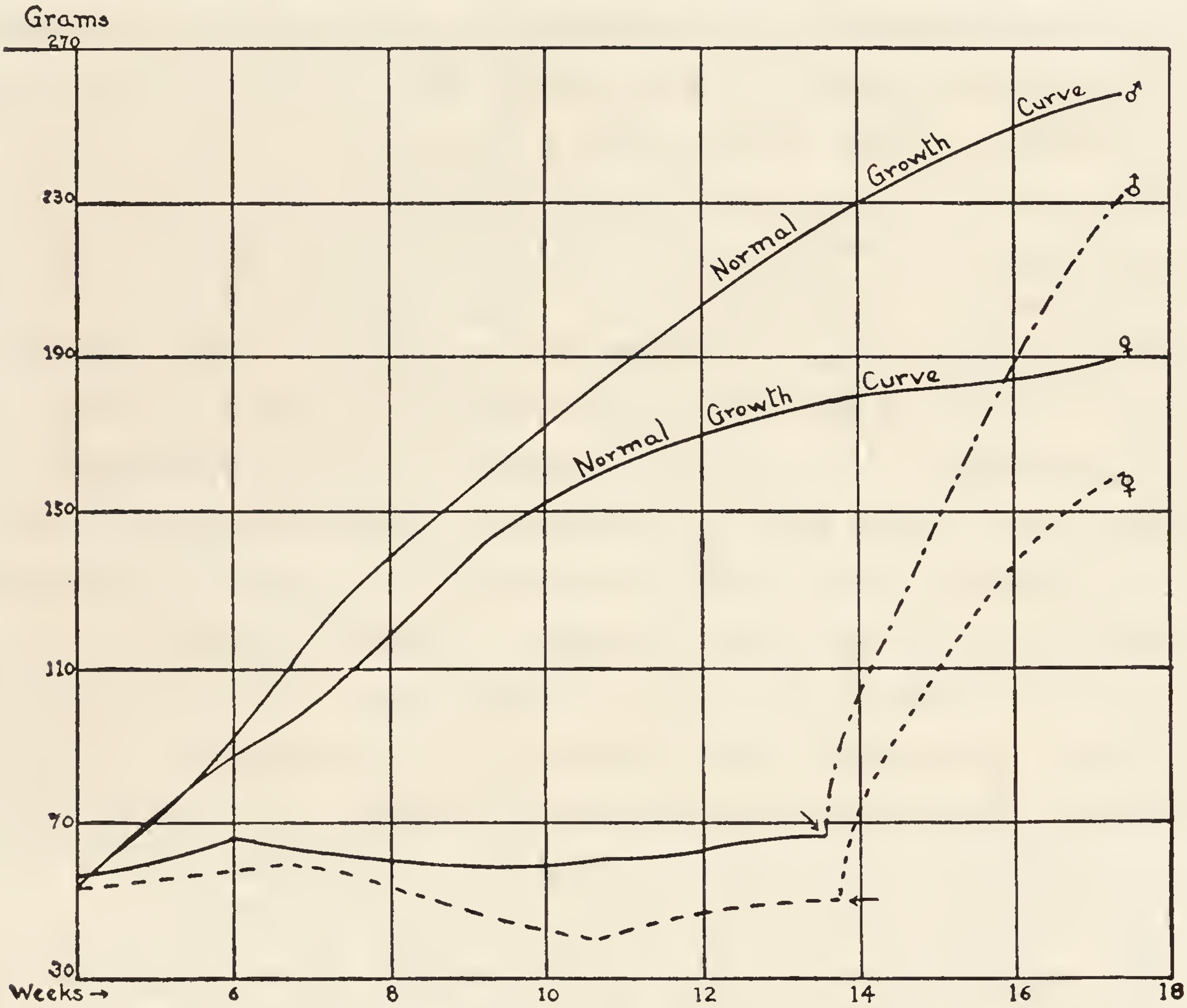


FIG. 32.—Growth Records of Rats on a Diet Insufficient in Calories Only.

These animals received a diet restricted only as to calories, which were about two thirds of their estimated requirement. For almost 14 weeks they barely maintained their weight. When they were given all they would eat, from the 14th week on, they caught up with the normal controls in about four weeks.

will soon come when a child can be tested periodically from birth until he is able to assume responsibility for securing his own health examinations. That 30 per cent or more of our American school children should be estimated to be undernourished is a warning as to ignorance and carelessness. While some of the underweight children are baffling problems, the majority of them yield to a hygienic mode of life, including an adequate diet; the others should be under the care of physicians, either privately or at child welfare sta-

tions, so that the fundamental causes of their physical inadequacy may be skillfully investigated and as far as possible removed.

The Causes of Undernutrition

Ordinarily we depend largely upon appetite as a guide to food consumption, but seldom is this adequate without intelligence to direct it and check the results of following its dictates. Just as an extra pat or two of butter stored every day for ten years may transform a 150 pound man into a case of obesity, so a consistent shortage of calories may result in undernutrition. This deficit may be unsuspected if the person follows his routine of three meals a day. As Morgulis has aptly remarked in his treatise on undernutrition: "A person, engaged in the performance of heavy work on a dietary allowance which supplies energy for mild tasks only, will be as truly in a state of chronic inanition as is one who through accident, disease or misfortune is obliged to sustain himself on a limited quantity of food. In either event there will be a negative balance between the income and output of energy, a shortage which the organism must make good by infringing slowly but none the less persistently upon its stored reserves." [1]

No appetite is entirely trustworthy; if no attention is paid to the energy value of the food, fluctuations in the amount eaten from meal to meal and day to day may be very great. In a study of the individual food consumption of a group of healthy and presumably well fed girls from ten to twelve years of age,[2] living in the same house and eating at the same table, there was found to be a great deal of variation in the amount eaten from day to day. This was especially true in regard to the dinners. By weighing each girl's food for a number of days it was discovered that the greatest single cause of this variation was the

[1] Morgulis, Sergius. *Fasting and Undernutrition*, page 261. E. P. Dutton and Co. (1923).

[2] Rose, M. S., and Gray, C. E. *Relation of Diet to Health and Growth of Children in Institutions.* Child Development Monograph No. 2. Bureau of Publications, Teachers College, Columbia University (1930).

presence or absence of milk from the menu. Within a month, 61 dinners weighed on days when milk was not given as a beverage averaged 619 calories, while 23 dinners when milk was supplied averaged 1,038 calories, an increase of 68 per cent. The study also showed that if the main dish and the dessert both happened to be low in calories when no milk was furnished a dinner might have only half as many calories as the one the next day.

Similar observations have been made by Wait and Roberts [1] at the University of Chicago in connection with studies of the energy intake of adolescent girls in institutions. Thus one of the girls consumed on Monday 1,964 calories, Tuesday 2,231, Wednesday 2,039, Thursday 1,804, Friday 1,110, Saturday 2,015, and Sunday 3,116. The difference between her maximum and her minimum was 2,008 calories, or 180.7 per cent of the minimum. The ease with which two people sitting at the same table can vary their food intake is shown by the two breakfasts from the same menu on page 112.

If one trusts solely to inclination, how much one eats depends largely upon the attractiveness of the food. The poor without vigorous appetites often find little inducement to eat in the character of the food on their tables. They cannot afford the alluring cream, butter, eggs, and fruit which add more calories than necessary to the diets of the rich, to say nothing of other foods which by attractive color, form, and flavor, enhanced by beautiful table settings, constantly give interest to the tables of the well-to-do and make eating the "most popular indoor sport." When college students plan and prepare a meal with regard only to pleasing their palates, they are apt to eat from 25 to 50 per cent more calories than when they provide for themselves a meal of minimum cost, and they regard the eating of the lesser number of calories in the low-cost meal as a much greater task.

[1] Wait, B., and Roberts, L. J. "Studies in the Food Requirements of Adolescent Girls. II. Daily Variations in the Energy Intake of the Individual." *Journal of the American Dietetic Association*, Vol. 8, page 323 (1932).

Two Breakfasts from the Same Menu

Food	Breakfast I		Breakfast II	
	Measure	Calories	Measure	Calories
Orange	½	50	1	100
Sugar	none	0	2 tsp.	40
Grapenuts	2 tbsp.	66	3 tbsp.	100
Sugar	none	0	1 tsp.	20
Cream	⅓ c. thin	150	⅓ c. thick	280
Toast	1 slice	50	2 slices	100
Butter	½ tbsp.	50	1 tbsp.	100
Coffee	1 c. clear	0	with ½ c. milk	85
Sugar	1 tsp.	20	2 tsp.	40
Total		386		865

Sometimes the root of undernutrition is worry—a proverbial destroyer of appetite. One young woman who wished to reduce her weight and found great difficulty in doing so was heard to exclaim, "I'd go down fast enough if I could only get up a big worry!" Children often suffer from underweight due to unhappiness and nervousness caused by an unfavorable home atmosphere. Emotional excitement causes outpouring of adrenalin and increases their energy expenditure while at the same time the environment and the character of the diet may tend to decrease appetite. The result is inevitably a discrepancy between energy intake and output and the child loses weight. Such children improve amazingly in regard to food consumption and body weight when changed to a more favorable environment.

Another common cause of inadequate appetite and undernutrition is fatigue. Several hundred college women in response to a questionnaire gave this as the commonest cause of failure of appetite in their own personal experience. In young children fatigue is undoubtedly very frequently responsible for reduced food intake, and probably affects in other ways the efficient use of food by the body. Children need to be carefully watched as regards the time spent in sleep and rest and to be safeguarded against playing to the point of exhaustion.

Many times loss of appetite is due to some physical

defect or disease: enlarged tonsils and adenoids, interfering with full respiration; infected teeth and tonsils, constantly poisoning the body; and latent infectious diseases such as tuberculosis are among the common causes of undernutrition reported by child health stations and clinics. Not only tuberculosis but also various diseases of the nervous system and of the alimentary tract seriously impair appetite and in this and other ways bring about undernutrition.

While simply increasing the total amount of food will result in higher intake of all the constituents which accompany the calories, better selection of the sources of the calories will yield still more satisfactory results. This is interestingly shown by two studies, one made by Sherman and Gillett in 1914–15 and the other by Gillett and Rice in 1928. Each study was based on the food purchased by approximately 100 city families on low incomes. In 1914 the most common errors in the diets of 92 of the families which were uninfluenced by educational work on the part of the nutritionist were too much meat and fish and too little milk, fruit, and vegetables, resulting in deficiencies in calories, calcium, and vitamins, often in iron and phosphorus. The study in 1928 included 100 families which had received no special instruction in the essentials of diet, but even these spent a larger percentage of their food money for milk, fruit, and vegetables, with a corresponding decrease in the amount spent for meat and fish. This wiser expenditure coupled with a greater amount of money spent for food, resulted in fewer dietaries with mineral and vitamin deficiencies.

In both the 1914 and 1928 groups there were also a considerable number of families which had received dietary instruction. These distributed their money so as to get more food value at less cost than the uninfluenced families of the corresponding period. None of the influenced families in the 1928 study were deficient in calcium and phosphorus, and their diets were also richer by 80 per cent in vitamins A and C. Vitamin B_1 was not estimated, but the strong emphasis on whole grain cereals, milk, fruits, and vegetables

undoubtedly made an equally great improvement as regards this vitamin. Summing up the results, Gillett and Rice [1] say: "The children in the influenced families were receiving a larger reserve of health, which should make them better able to resist disease, yet their food was costing less than the food in the uninfluenced families. This saving in the amount spent for food more than covers the cost of the teaching. The influenced A. I. C. P. families in the 1928 study spent on the average seven cents less per adult male unit per day than did comparable uninfluenced families. If we use the average composition of 100 families served by the Nutrition Bureau in 1928 as the basis for calculating the families in terms of adult male units, this saving of seven cents per adult male unit per day would represent a saving of seventy-three dollars per family per year or 7,300 dollars for 100 such families for one year."

Safeguarding Digestion

Sometimes attempts to gain weight are discouraging because the person's digestive system is unequal to the new demands abruptly made upon it. This may be due in large measure to a deficiency of vitamin B_1 the result of a small intake of a diet poorly supplied with this vitamin. The deficiency may be no more than enough to produce a poor tone of the walls of the alimentary tract, but since good digestion is very directly related to vigorous, well coördinated movements in all parts of the digestive system, minor digestive ills result, which are a common topic when people begin to talk about food. The great advances in the feeding of infants and young children without digestive upsets are probably due more to the recognition of vitamin B_1 as essential to nutrition than any other one factor. The first thing that a person who wishes to increase food intake should do is to choose foods rich in this vitamin. The thin

[1] Gillett, L. H., and Rice, P. B. *Influence of Education on the Food Habits of Some New York City Families.* New York Association for Improving the Condition of the Poor (1931).

person needs first to make himself as well as possible, so he will agree with his food. In addition there are some precautions which it is well to take. For one thing increases should not be too sudden. The girl who learned that peanut butter was high in calories and proceeded to dispose of half a pound (1,370 calories) a day in addition to her regular diet came quickly to grief because she had given her alimentary tract a task to which it was unaccustomed. It is not enough to know how much energy is needed. We must also know how to furnish it so as to prevent disturbance of the machinery. The three kinds of fuel food are used to best advantage when carbohydrate predominates, and neither fat nor protein is present in very high proportion. While fat is our most concentrated form of fuel, it has to be used with discretion or digestion may be disturbed and we will defeat our own ends. Protein is easy to digest but is best used in moderate amounts if we would get its full contribution to the total energy intake. Protein alone burns wastefully, many calories being then unavailable for either work or storage. (See pages 40, 41.) Carbohydrate in the form of sugar is most attractive, but sugar blunts appetite unless carefully managed. Mrs. Squeers of Dotheboys Hall knew this, for she gave treacle (molasses) to her wretched protégés "partly because it spoils their appetites and comes cheaper than breakfast and dinner." Sugar in concentration irritates the stomach and may be the cause of headaches, skin eruptions, and other ills. Starch is easy to digest, but too much may ferment before it has had time to be absorbed and so do more harm than good.

For the greatest comfort, food should digest fairly rapidly. This is especially true if a larger amount than usual is to be eaten. As rapidity of digestion is fostered by having the food in fine particles when it enters the stomach, mastication becomes a special virtue. Toast, zwieback, triscuit, bread dried hard in the oven, crusty rolls, crisp, dry corn flakes, grapenuts, shredded wheat, etc., are desirable forms of bread, because they induce mastication and in the process

absorb saliva like a sponge, thus further accelerating the speed of their digestion.

Fat, digesting slowly and tending to retard the digestion of other foods, especially those rich in protein, must not be used too freely, for slow digestion tends to impair appetite for the next meal. Fat meats, such as pork, are an excellent example of food slow to digest because of fat mixed with the protein.

The principles of feeding in undernutrition find special application in tuberculosis, where the body's ability to fight the disease depends upon developing a good state of nutrition in spite of an almost invariably fickle appetite and poor digestion. Fresh air, sunshine, rest, a diet of the highest quality, appetizing and easy to digest, at regular times, and in specified amounts are prime features of treatment.

The exact number of calories which any person will require to induce gain in weight cannot be determined definitely in advance, but must be gauged by watching the scales. Those who do not fatten easily need all the more to learn to live on a high nutritional plane. It may not be possible for them to get much fatter, but they will surely feel better, as they thus replace what they spend and safeguard themselves against serious undernutrition.

Section 2

SURPLUS OF CALORIES

Who does not remember Mrs. Manson Mingott, the "venerable ancestress" in *The Age of Innocence*, whose habit it was to sit in her room on the ground floor waiting for life and fashion to come to her, since she was unable to follow them even to the grand reception room of the second floor of her Fifth Avenue mansion? Mrs. Wharton has described her inimitably: "The immense accretion of flesh which had descended on her in middle life like a flood of lava on a doomed city had changed her from a plump active little woman with a neatly-turned foot and ankle into something

as vast and august as a natural phenomenon. She had accepted this submergence as philosophically as all her other trials, and now, in extreme old age, was rewarded by presenting to her mirror an almost unwrinkled expanse of firm pink and white flesh, in the center of which the traces of a small face survived as if awaiting excavation. A flight of smooth double chins led down to the dizzy depths of a still-snowy bosom veiled in snowy muslins that were held in place by a miniature portrait of the late Mr. Mingott; and around and below, wave after wave of black silk surged away over the edges of a capacious armchair, with two tiny white hands poised like gulls on the surface of the billows." [1]

Many another woman has been forced by the accumulation of body fat so common with advancing years to keep off her feet or suffer because her body has become too heavy for them to carry. We realize the handicap of obesity when it thus impedes locomotion and engenders flat foot, but we should also realize that the internal organs are working under a handicap like that of the feet. The muscles when clogged with fat become soft and flabby; the heart in particular suffers in this way. The circulation of the blood is impeded and this in turn makes the work of the weakening heart more difficult and the strain on the blood vessels greater. Liver, kidneys, and pancreas all are at a disadvantage, and how long they can continue to function properly depends on their native endurance. There is no guarantee that a pancreas able to take care of a 150-pound body can take equally good care of one weighing 300 pounds; in fact, there is evidence enough to be strongly suggestive that diabetes is the penalty for obesity. Certain diseases have long been known to be associated with overweight. Life insurance companies are reluctant to place standard insurance on people with marked overweight, and where it is excessive, may refuse insurance altogether. This attitude of the insurance companies shows that they consider overweight a very serious disability.

[1] Wharton, Edith. *The Age of Innocence*, page 25. D. Appleton and Co. (1920).

Mode of Life and Food Consumption

It is clearly important to check the tendency to increasing weight by such changes in mode of life, especially in diet, as will prevent any undue accumulation of body fat. At age 50, people from 20 to 30 pounds below the ordinary average for their age seem to be in best condition. We have seen that the basal metabolism of adults falls slightly year by year. Exercise, too, seldom fails to diminish in duration and in intensity; and emotional intensity declines as the strife of life abates and the fruits of labor are enjoyed, so the stimulus of the adrenal glands to energy expenditure becomes less. Yet the appetite for food continues or even increases. So, more and more, food is eaten which is not needed and the extra fuel is stored as body fat. While some persons undoubtedly store fat much more readily than others, it is not generally attributable to any lowering of their basal metabolism. On the contrary it is interesting to note that when a person weighing perhaps 150 pounds adds 75 pounds of body fat the basal metabolism per square meter of body surface will remain practically the same as before, although this change in body composition as shown in Chapter IV would lead us to expect a definitely lower rate. It has been found that when the excess fat is reduced by restriction of the calorie intake the metabolism is also reduced. This explains why a diet which will cause combustion of body fat in the early stage of weight reduction will later have to be further lowered to bring about continuing loss of weight.

An inclination toward obesity may be constitutional; a cheerful disposition, a very stable nervous system, incapacity for worry, ability to work with great economy of muscular effort, lack of interest in cold baths or hot athletic contests may be a part of one's inheritance. Two boys on roller skates were at the foot of a hill. The one was long and lanky, with not a gram of spare fat. The other was short and bulgy, probably 30 or 40 per cent overweight. The thin boy skated as fast as he could to the top of the incline, and when he

coasted down made as big a jump as possible at the bottom. The fat boy stood at the bottom, slowly making a very small circle on his skates and no other move except to measure the jump of his companion. Is it not easy to see why one was thin and the other fat? When riding in automobiles, watching movies or baseball games, and sitting at bridge parties are the most active forms of sport, how many calories in excess of the basal metabolism will be spent? If we propose to lead sedentary lives, we should learn to lead them well. The greatest obstacle is habit. One must plan a food program which one can remember. The best way is to determine the number of calories one should have for each meal and see that one does not exceed the limit. The few calories permitted must be chosen from foods rich in minerals and vitamins so that no dietary essential except calories will be reduced. If it is difficult to resist whatever may be served at the table it may be better to stay away from the table for one meal (breakfast or luncheon), taking only some fruit by one's self. This plan keeps one from falling into one's former habits; provided of course, that one does not visit pantry, refrigerator, soda fountain, nor afternoon tea table and there make up everything lost by one's self-denial at meal time. It is usually necessary for adults to limit calories to the basal metabolism or even a little less, as with restriction there will be some lowering of the metabolism. But it is exceedingly important to remember that the limitation must be in *calories only*. Every other dietary essential must be kept at the optimum level. The modern science of nutrition has shown the way to make a reducing diet which is not only safe but will actually improve health. The details of planning such a diet are discussed in Chapter XXII.

The Control of Hunger

Hunger is a great inconvenience when one wishes to reduce one's food intake. It is well to remember that hunger is the sign of a vigorous stomach emptying itself quickly and not the signal of danger of immediate starvation. Hunger pangs

will seem less alarming if reckoned at their true value; nevertheless they are extremely uncomfortable and hence it is well to seek some way to allay them. Sometimes drinking water will assuage them temporarily. Eating food with much vegetable fiber is a help as it gives a sense of fullness, which is a part of the normal satisfaction of hunger. There need be no limit to the amount of lettuce, cabbage, string beans, celery, chard, brussels sprouts, asparagus, and other greens, and there should be a real effort to increase the amount of such food to many times what is ordinarily eaten. Instead of two or three lettuce leaves, take at least half a solid head; instead of a bit of cabbage as a side dish, take two or three cupfuls of raw shredded cabbage. Raw fruit such as apples, oranges, grapefruit, and other fruits in season should so far as possible take the place of other desserts. Some fat is a help in controlling hunger and can be used if sufficient attention is paid to the total calories, which, of course, are rapidly increased by this concentrated form of fuel. The fat should be put where it will count most, on the table where one can see it, and not in the food while cooking. Mineral oil, which has no food value, may be used in making salad dressings, and vegetable gelatin, also devoid of calorie value, may be the foundation of some acceptable desserts.

With a low calorie intake, food at more frequent intervals is often desirable. In the middle of the morning and again in the afternoon, a sweetened beverage, carrying a few calories of sugar, may be a real advantage. A weak lemonade or orangeade may be even better than a cup of sweetened tea. The fruit juices help to keep the mineral and vitamin content high. All calories so taken must be counted, of course, as a part of the day's total.[1]

Adjusting Energy Intake and Energy Expenditure

The scales should be watched week by week. Gain or no gain is the final test of the diet. If one is gaining, there are

[1] For assistance in planning diets, see Chapter XXII; also Rose, M. S. *Feeding the Family*, 3rd edition. The Macmillan Co. (1929); Peters, L. H. *Diet and Health with Key to the Cal-*

too many calories. Adjust them until weight remains stationary; or, if overweight, until losing at the desired rate, which should not be over a pound a week. Remember that 200 calories a day stored mean 17 pounds of body fat in one year, and that one insignificant chocolate caramel yields 50 calories; one small bar of sweet chocolate, 150 or 175 calories; one sundae at the fountain, 500 calories; one chocolate malted milk with ice cream, 700 calories.

Loss in weight may not be regular. Fat burned off may be temporarily replaced by water with little or no change in weight for some time. Then water may be lost rapidly and weight fall, only to remain stationary again as water accumulates once more. Later, this water will be lost, and then the reduction in fat, which has been going on all the time, becomes evident. If the calories taken are not above the basal metabolism, body fat must be used as fuel. There is no escaping this law. If the body persistently retains water, so that after some weeks the weight has not gone down, a physician skilled in the pathology of the endocrine glands should be consulted. The pituitary gland, especially, exercises a control over the water of the body. For further discussion consult the sections relating to water.

In addition to limiting the calories, it is desirable to increase the energy expenditure by exercise and cold showers. The exercise should be moderate and over a considerable period of time; the "daily dozen" should be raised to a "daily score" and the more exciting the better. Sport is better than routine exercises. The cold showers not only raise basal metabolism at the moment, but continue to stimulate it for some time afterwards. A bath with the water at about 60° F. has been found to double the energy expenditure, and one with the water at 40° F. may be counted on to treble it! Of course, one must very gradually accustom himself to such cold baths, beginning with water about 65° F.

ories. The Reilly and Lee Co. (1921); Axtell, L. E. *Grow Thin on Good Food.* Funk and Wagnalls Co. (1930).

Obesity in the Young

Obesity is not characteristic of youth. Under thirty years of age the natural tendency is toward under- and not over-nutrition, yet a few children are overweight for height and age. Sometimes this is because they are lazy and overfed; increasing their activity and curtailing sweets (usually the cause of surplus of calories in such cases) will bring them to a better condition. There is, however, a type of obesity of which the fat boy in Dickens's *Pickwick Papers* is an example. "The fat boy rose, opened his eyes, swallowed the huge piece of pie he had been in the act of masticating when he last fell asleep, and slowly obeyed his master's orders." Here are all the conditions for fat storage—a good appetite, movement reduced to a minimum, and a pathological metabolism attested by the chronic somnolence—"He's always asleep, goes on errands fast asleep and snores as he waits on the table." This is a not entirely rare type of endocrine disturbance in which structures in the brain and possibly the posterior lobe of the pituitary gland play a part. Such a case should be referred to an expert in endocrinology.[1]

Obesity is a handicap to children, because they do not fit so well into the regular athletic and play program and are more liable to accidents and strains. Veeder, from a four-year study of 200 private schoolboys ranging from nine to seventeen years of age, calls the overweight boy as much of a problem as the underweight. "The fat boy is too heavy to fit in with hard exercise or play, such as football, with boys of his own class and age, and too young and immature to play with boys of his own weight but older in years and stronger. In games requiring more skill, such as baseball and tennis, they are decidedly awkward and backward as a group and hence we find them with the tendency to withdraw from competitive play and loaf, with the result that these overweight boys, who are in particular need of exercise,

[1] For an interesting discussion of the endocrine glands see Hoskins, R. G. *The Tides of Life*. W. W. Norton and Co. (1933).

are the ones who have to be continually driven and supervised." [1]

Ordinarily the basal metabolism of overweight children is within the normal range when calculated to surface area. Dr. Anne Topper and Dr. Hannah Mulier, of the Pediatric Service of Mount Sinai Hospital, New York City, in a study of 78 boys and girls from 14 to 16 years old, found this to be true in about three fourths of the cases, and in another study of 25 boys and girls between 5 and 14 years of age, they could find no evidence of any endocrine disturbance, though the children were from 20 to 76 per cent overweight. The basal metabolisms were high normals or above. In every case there was a history of overfeeding. Many had voracious appetites so that the total calorie intake was in some instances twice as much as needed. The diets were rich in carbohydrates and fats, with very little in the way of vegetables or fruits.

Treatment consisted in a careful regulation of the total calories, the intake being determined by the basal metabolism, coupled with care to select foods which would keep the quantities of protein, and the various minerals and vitamins up to the appropriate amounts for children of their ages. Active physical exercise, such as walking, roller skating, tennis, handball, and swimming, was also prescribed. Under this regimen for about four and a half months the children's weekly average loss was three quarters of a pound and their gain in height above expectation. Furthermore they acquired a feeling of well-being, an increased capacity for physical activity, an increased interest in all school activities, and greatly improved eating habits, with a loss of their passion for food.[2]

It does not seem wise to reduce the weight of a growing child except under special medical supervision, but it may be possible to hold his weight stationary until by a care-

[1] Veeder, B. S. "The Overweight Child." *Journal of the American Medical Association*, Vol. 83, page 487 (1924).

[2] Mulier, H., and Topper, A. "Treatment of Obesity in a Group of Children." *American Journal of Diseases of Children*, Vol. 47, page 25 (1934).

fully regulated diet and by suitably planned and if possible exciting exercise he has lowered his excess of fat. As a rule, children do not enjoy being obese and are willing to coöperate in measures to bring their weight to normal, but they gain easily and care must be given to them over a long period of time. Children easily learn to count their own calories and can thus help themselves. It is important to see that each such child gets as a part of his ration three glasses of milk and one egg daily, at least 300 calories of whole wheat bread and potatoes together, some fruit and some vegetable other than potatoes at every meal, at least one teaspoonful of cod liver oil daily, no candy, cake, preserves, syrups, etc., and nothing whatsoever between meals except plenty of water.

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CHAPTER VII

PROTEIN AS BODY BUILDING MATERIAL

The Essentials for Body Building

The beginning of a human being is an egg too tiny to be studied with the naked eye. Initiated by the union of sperm and ovum, a complicated system of chemical processes which we call life at once enables the minute organism to take up materials from its environment for its own growth. During its prenatal life the human fetus increases its weight more than five million times. By the fourth month of intrauterine life it may have attained a weight of 36 grams; at birth it will have increased this latter weight one hundred times. Even after birth the increase in substance is great. A newborn baby weighs on the average from 7 to 7.5 pounds; the adult into which he grows may weigh twenty to thirty times as much. The calories represented in the body of a four months fetus are about ten; in the infant at term, about 4,000, in the average adult man, over 50,000 from protein alone and probably half as much more from fat and glycogen. The major portion of the energy-yielding materials ingested must be spent in the maintenance of internal and external activity, but a certain part must also be retained for growth. Up to the time of birth the human fetus stores daily an average of at least three grams of protein and eight grams of fat. An infant ingesting 520 calories and gaining 3 grams of protein and 3 grams of fat in a day will have stored 40 calories, or 8 per cent of the total calories eaten.

The protein is an essential component of every living cell in the body and makes up a large part of the solids of a muscle cell; a small portion of the fat enters into the composition of nervous tissue; the rest is stored as adipose tissue. Carbohydrates we find also in the living body, not

only as a source of energy but as constituents of certain indispensable proteins and certain other compounds found in the brain and nerves. Even starvation does not deprive the blood of all its sugar nor the heart of all its glycogen.

Thus from the stream of energy-yielding proteins, fats, and carbohydrates continually passing through the body as we eat, digest, and assimilate our food, materials for constructive purposes are withdrawn as needed. Similarly water, whose constant flow through the body is one of the conditions of life, is an essential part of the body structure, constituting about three fourths of the body weight in the newborn and about two thirds in the adult.

In addition to proteins, fats, carbohydrates, and water, we find in the body an assortment of mineral elements including calcium, chlorine, copper, fluorine, iodine, iron, magnesium, manganese, phosphorus, potassium, silicon, sodium, and sulfur. These are commonly referred to by the inclusive term mineral elements. Equally important with the supply of energy is the supply of each chemical element in the amount needed. A shortage of any one, no matter how minute the daily requirement, will interfere with normal nutrition. The fetus stores on the average only about three fourths of a gram of assorted mineral salts per day. In the fortieth week of pregnancy, when the total daily storage is at its height, it has been estimated to be for phosphorus, 0.18 gram; for calcium, 0.3 gram; and for magnesium, 0.009 gram. The other elements must be retained in still smaller amounts. Yet only when every element is properly represented can the body maintain its health, replace worn-out parts, and construct new materials in the process of growth.

Protein as the Source of Amino Acids

Muscular work is done preferably and most economically at the expense of carbohydrate food. Mixtures of fat and carbohydrate in which carbohydrate predominates are burned with practically the same ease as pure carbohydrate.

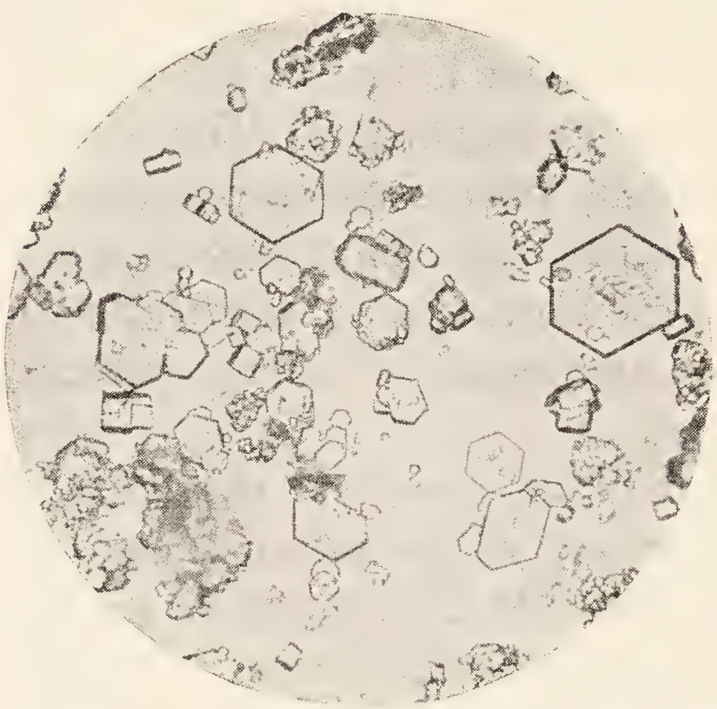
Fat alone is utilized with less ease than a mixture of the two and with a "cost" of from 8 to 12 per cent of its energy value. Protein can be economically used when a small proportion is mixed with carbohydrate or carbohydrate and fat, but when taken as the sole source of energy, is burned at a rate that is wasteful in the extreme. As long as carbohydrate and fat are available, muscular work is not done at the expense of the protein supply. When protein is used as fuel, the nitrogen which it contains is not an asset but a liability, to be got rid of as speedily as possible. The protein is transformed within the body into simpler compounds which will be described presently and the nitrogen is excreted in the urine, chiefly in the form of urea, together with a relatively small amount of ammonia. Then the protein, freed of its nitrogen, is burned.

When protein is used as building material the story is very different. Then the nitrogen is the prime consideration. Every living cell is continually demanding it for upkeep, working it over into living tissue, or using it for the construction of hormones, and ultimately discarding it again in the form of other simpler compounds (chiefly uric acid from all kinds of active cells and creatinine from muscle cells) which are excreted in the urine. In the human adult the creatinine excreted ranges from 7 to 11 milligrams per kilogram of body weight or less than one gram per day; the uric acid averages about 0.6 gram per day; both together are usually less than 10 per cent of the total nitrogen of the urine.

There is thus a maintenance requirement for protein, which continues throughout life and is independent of muscular activity. In addition to this maintenance requirement for every one we have in youth, as already indicated, a growth requirement—an additional and more specialized need of protein for the building of new body substance. This growth requirement makes the total protein requirement of childhood higher in proportion to size than that of the adult. Only under certain circumstances do we have in

adult life a growth requirement superimposed on the maintenance requirement; these are chiefly:

(1) In athletic training, when muscles increase in size.
(2) After a wasting disease, when muscles are regaining substance lost.
(3) In pregnancy, owing to growth of the unborn child and to some development of the maternal organism.



(Courtesy of Dr. G. L. Keenan)

Fig. 33.—Crystals of the Amino Acid Cystine.

In order to understand protein requirements and how to meet them, it is necessary to know something about the chemical structure of protein itself. The term stands for a large number of related substances all made by the union of simpler substances containing nitrogen, called amino acids. There are 22 of these commonly found in food and body proteins, all having certain characteristics in common, but each one exhibiting properties which mark it as a distinct chemical entity. The names of these 22 common amino acids are as follows:

Alanine	Leucine
Arginine	Lysine
Aspartic acid	Methionine
Citrulline	Norleucine
Cystine	Phenylalanine
Glutamic acid	Proline
Glycine	Serine
Histidine	Threonine
Hydroxyglutamic acid	Tryptophane
Hydroxyproline	Tyrosine
Isoleucine	Valine

A protein is a very complex substance. We may get some idea of how it is constructed from the amino acids

listed above if we think of a large assortment of beads of 22 kinds, each a different color and size and many of each kind in the lot. To represent a protein we may select one sample of each of our different beads and arrange a figure; or we may take the same 22 amino acids, some kinds singly, others by threes or fours, perhaps some by the dozen, and arrange another figure of quite a different pattern. Each would typify a protein but the two would have quite a different composition, though built from similar units. Some proteins have only 17 amino acids represented in their structure, others only 15 or 16, and these also may be varied by different proportions of each of the kinds present. Here for example is the chemical analysis of two proteins, casein from milk and zein from our common Indian corn.

THE AMINO ACID CONTENT OF TWO KINDS OF PROTEIN

	CASEIN PER CENT	ZEIN PER CENT
Alanine	1.9	9.8
Arginine	3.8	1.8
Aspartic acid	4.1	1.8
Cystine	0.3	1.0
Glutamic acid	21.8	31.3
Glycine	0.5	Absent
Histidine	1.8	0.8
Hydroxyglutamic acid	10.5	2.5
Hydroxyproline	0.2	Absent
Leucine (and Isoleucine)	9.7	25.0
Lysine	6.3	Absent
Phenylalanine	3.9	7.6
Proline	8.0	9.0
Serine	0.5	1.0
Tryptophane	2.2	Absent
Tyrosine	6.5	5.9
Valine	6.7	1.9

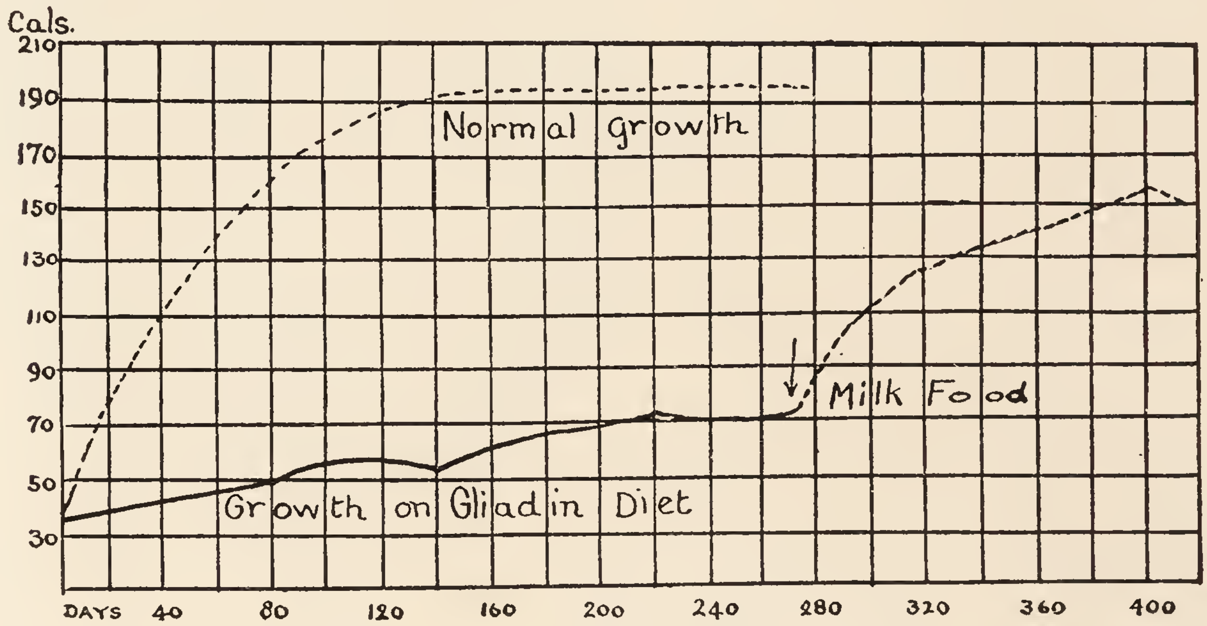
It will be noted that the proportions of amino acids in the two are very different and that, while casein is not entirely lacking in any amino acids in the list, zein lacks four.

Some amino acids are more important than others. Glycine and alanine, which are relatively simple, can be made

from more complex ones, just as a suit for a very small boy may be cut from his father's large one. We know of ten, however, which cannot be thus provided. They are:

Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophane
Lysine	Valine

These must be present in the proteins of the food, for they are as important in their way as the hormones, insulin,



(*Courtesy of Drs. T. B. Osborne and L. B. Mendel*)

FIG. 34.—The growth record of a young rat placed at weaning time upon a diet containing gliadin as the sole protein, and kept on this diet for 276 days. At this time milk food replaced the gliadin food, and the animal was able to grow at a good rate although of an age at which normal rats have usually ceased to grow.

thyroxin, etc. Gliadin, one of the proteins of wheat, is deficient in lysine. The poor growth record of an animal maintained on a diet with gliadin as the sole protein, is shown in Fig. 34. When milk, rich in lysine, was added to the diet, growth was promptly resumed. When pure lysine was added in place of milk the result was the same.

A protein can be resolved into its component amino acids by artificial digestion, and one or more of the amino acids removed. When histidine is removed from casein in this way and the remainder of the amino acid mixture is fed, not only is the growth of the animals retarded but

their health becomes seriously impaired. The result of feeding such a histidine free diet for 169 days as compared with the result of feeding the same diet plus histidine is shown in Fig. 35.

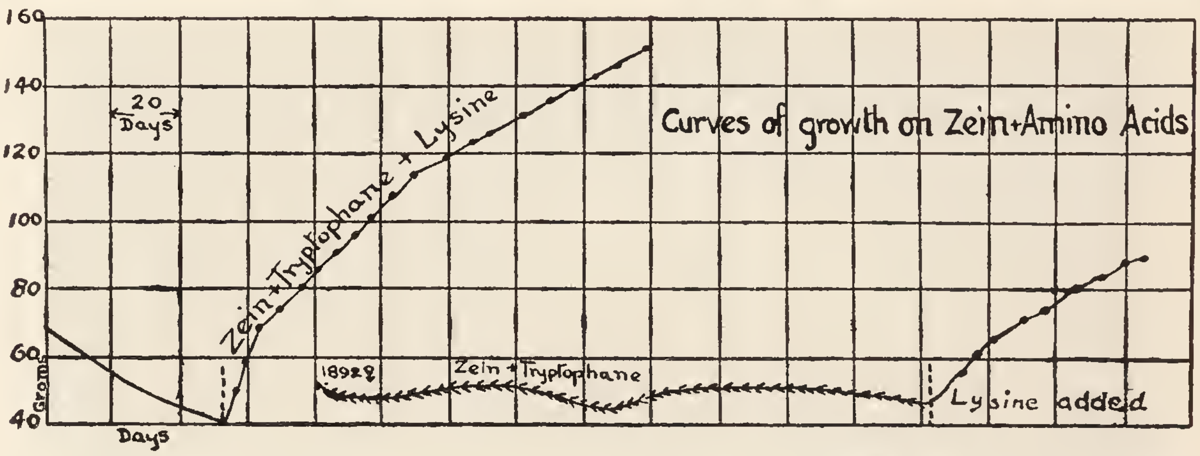
When zein, one of the proteins of corn, is the only source of amino acids in an otherwise adequate diet, young animals not only fail to grow, but lose weight rapidly. If now some

(*Courtesy of Dr. W. C. Rose*)

FIG. 35.—The upper rat was on a diet adequate in all respects. The lower had a diet similar in every way except that histidine had been removed and arginine substituted for it. Histidine is thus shown to be an indispensable constituent of the diet.

tryptophane be added, the loss of weight stops but there is no growth, as shown in Fig. 36. In this case the weight remained practically stationary for about 180 days on zein plus tryptophane. The reason why there was no growth is that zein also lacks lysine. When this was also incorporated into the ration, growth began at once.

The discovery of threonine was accomplished in 1936 by Professor W. C. Rose of the University of Illinois, after his attempts to make animals grow on a mixture of pure amino acids representing as nearly as was then possible the natural mixture in pure casein had resulted in failure, showing that some essential amino acid was still unknown. By removing the known amino acids from artificially digested casein,



(*Courtesy of Dr. L. B. Mendel*)

FIG. 36.—The solid line shows the decline in weight when zein of maize is the sole protein of an otherwise adequate ration. With zein plus tryptophane weight is maintained, but there is no growth. When lysine is added as well as tryptophane, normal growth is possible.

and testing the residue for its growth promoting properties, he proved that at least one other amino acid was present in it. Several years of patient research finally led to the isolation and identification of threonine. Equipped with 20 pure amino acids, Rose was able to pursue further the question as to which of the twenty are indispensable in the sense that they cannot be constructed from any of the others in the body as needed, and added several besides threonine to those already so classified, and finally, in 1937, crowned these achievements by showing that a young rat could be made to grow at an excellent rate when only the 10 amino acids listed on page 130 were the source of all the nitrogen for the building of new body protein. This opens up a new phase of research in amino acid metabolism, the study of just how much of each essential amino acid is required for growth and whether under other conditions, such as pregnancy and lactation, different amino acid combinations may be necessary.

Food Sources of Essential Amino Acids

Proteins which will maintain life and promote growth are sometimes called "complete" to distinguish them from proteins which lack some amino acid or acids essential to growth. These latter are called partially incomplete if they

FIG. 37.—The effect on growth of a diet in which the protein is of good quality but insufficient in amount. The diet of the upper rat contained one fourth as much casein as that of the one below. In other respects the two diets were practically alike. Both rats are the same age, 112 days.

will maintain life, and totally incomplete if they will neither maintain life nor support growth.

The fact that animals on a diet in which gliadin, low in lysine, is the only source of amino acids will remain in good health over long periods, although stationary in weight, indicates some essential difference between the maintenance of the organism and the construction of new substance. Animals on a diet in which casein is the sole source of amino acids will grow normally if the amount is sufficient but not if it is too small. When the casein is limited to 4 per cent, there will be practically no growth, but the animals remain in excellent condition over long periods because all the indispensable amino acids are present, though some are in too

small amounts to permit growth. On the gliadin diet, no increase in the amount of protein will make good the deficiency, since the essential lysine is too low. On the casein diet, it is only necessary to increase the amount to the 18 per cent level to secure excellent growth as shown in Fig. 37.

Proteins of various kinds are associated in many foods. Some foods have very little in proportion to their weight,

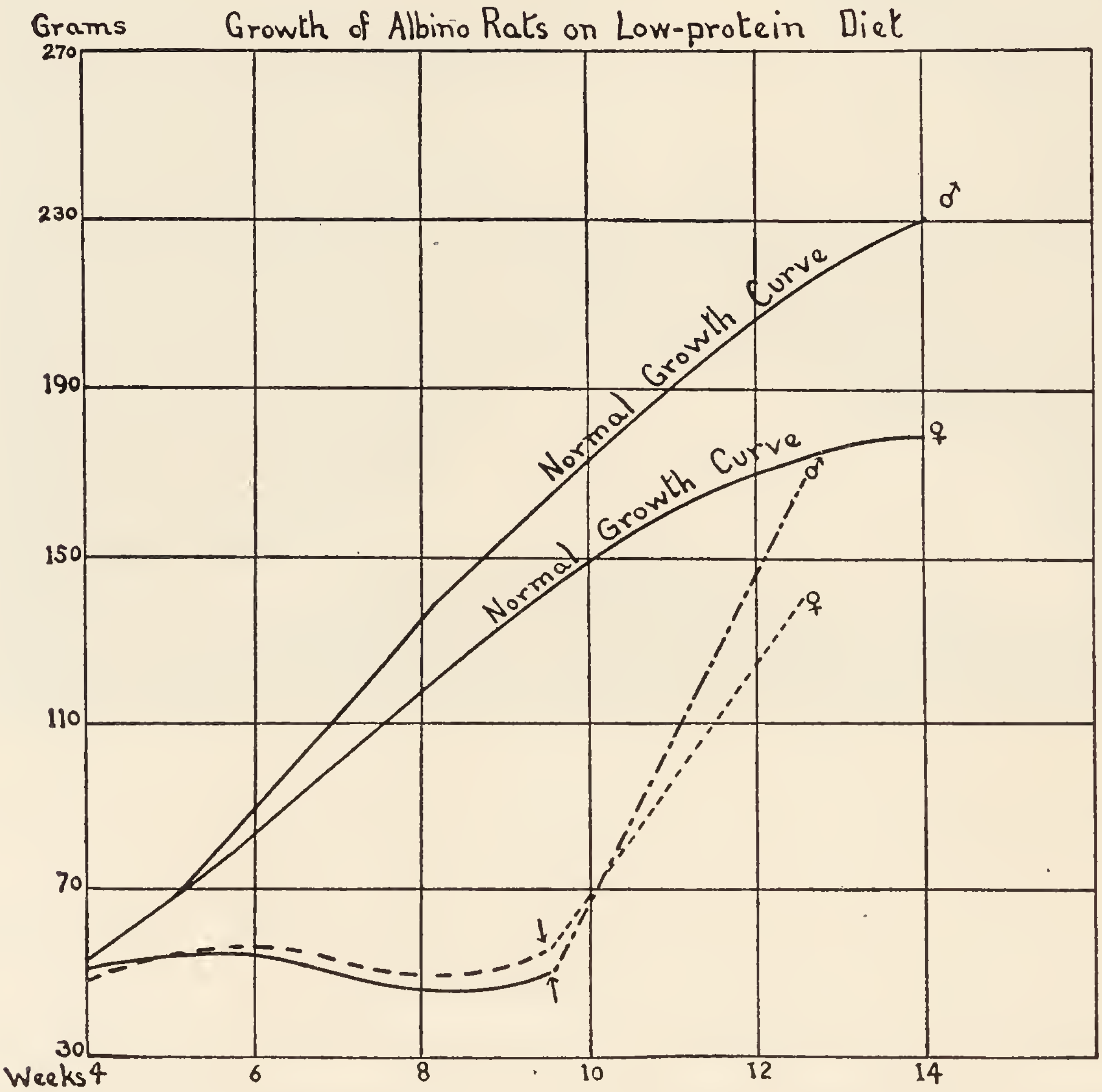


Fig. 38.—Growth curves of two rats restricted for nine weeks to one fourth the amount of protein required for normal growth. When the quantity was increased the resumption of growth was very rapid.

such as most fruits and vegetables. Others are very rich in protein, as eggs, cheese, nuts, and lean meats of all sorts, "fish, flesh, or fowl." Cereals are not very rich in protein, but on account of the relatively large amounts eaten by the human race are a source of considerable importance. Among other vegetable foods, the legumes, especially peas, beans, and peanuts, are comparatively high in their yield of protein.

Tables giving simply the total amount of protein present tell us nothing, however, about the kinds of protein occurring in the different foods.

CHARACTER OF PROTEINS IN SOME COMMON FOODS

Food Materials	Chief Kinds of Protein Present	Complete or Incomplete
Almonds	Excelsin	Complete
Cheese	Casein Lactalbumin	Complete Complete
Corn	Glutelin Zein	Complete Incomplete (lacks lysine and tryptophane)
Eggs	Ovalbumin Ovovitellin	Complete Complete
Gelatin	Gelatin	Incomplete (lacks tryptophane and tyrosine; high in lysine)
Lean meat	Albumin Myosin	Complete Complete
Milk	Casein Lactalbumin	Complete Complete
Navy beans	Phaseolin	Incomplete
Peas	Legumin	Incomplete
Soy beans	Glycinin Legumelin	Complete Incomplete
Wheat	Gliadin Glutenin	Partially incomplete (low in lysine) Complete

The table above shows the chief kinds of protein in some of our common food materials with reference to the nutritive efficiency of their proteins. From this it will be seen that in ordinary daily life our chances of getting none but incomplete proteins are small; in animal food, such as milk, cheese, eggs, and meat, the various proteins present are all complete, but in vegetable foods very commonly an incomplete protein is associated with a complete one; occasionally, as in the case of the navy beans, the total protein content

seems of relatively poor quality. The supplementing value of one protein for another must, however, be kept in mind. The supplementing value of milk is exceedingly high. An instance is furnished by an experiment on growing pigs, in which one lot received protein only in the form of corn, which, it will be noted, contains the incomplete protein zein not compensated for by the complete protein glutelin; the other lot was given corn plus casein equal to about one tenth of the corn. The corn lot grew in 180 days from an average initial weight of 25.3 to an average final weight of 37.6 pounds, whereas the average change in the corn-casein lot was from 31 to 142 pounds. Here a comparatively small addition of casein changed the ration from one that permitted practically no growth to one that induced approximately two thirds normal growth.

The nutritive value of a protein mixture can be predicted only as the amino acid content is known. As yet such analyses of proteins are not numerous. We must, then, in each case of uncertainty have recourse to laboratory animals and by carefully regulated feeding experiments determine the efficiency of any food or mixture of foods in question. Since this is laborious and time-consuming, it is a comfort to know that the protein deficiencies of cereal grains and legumes can readily and economically be made good by the liberal use of milk in the diet, and less cheaply but also effectively by eggs and other animal foods.

Protein Requirement

The nutritive value of any protein or mixture of proteins depends, as we have already seen, upon the assortment of amino acids which it furnishes and their relation to the needs of the cells. The efficiency of the amino acid mixture determines the quality of the total protein of the diet. In the full-grown man or woman considerations of quality are not so pressing as in the young child, because we are concerned chiefly with the conservation of tissues already formed, and even an incomplete protein like the zein of

maize, inadequate for maintenance and incapable of supporting growth, is capable of protecting the body tissue to the extent of 73 per cent. But body building can proceed only when the zein is supplemented by the amino acids tryptophane and lysine. The situation is similar to that in which the builder of a frame house with brick foundation would find himself if there should be delivered plenty of wood for walls and glass for windows but no bricks. Obviously construction would be held up till the bricks were forthcoming.

In infancy growth proceeds at such a rate that the newborn child doubles its weight in six months and triples it in a year, and we find that as much as one third of the protein intake may be stored as body protein. Rubner even reports a study of a premature infant who for 38 days retained for growth one half the protein eaten. To get the best storage, the protein of the food must be in itself efficient in promoting growth and the supply of carbohydrate and fat must be liberal enough to protect the protein from being burned as body fuel. Milk is distinctly richer in tyrosine, tryptophane, and lysine than the common run of food proteins, and the amino acids least liberally supplied are those most easily derived from other foods. With a full quart of milk in the daily dietary of the growing child, the need for protein is so well met that the other foods should be selected with reference to other equally important dietary factors.

Because the protein requirement during growth is high, we cannot assume that there is no limit to the amount which can be given with profit. Both Holt and Hoobler have remarked in their studies with human infants failure to gain and other unfavorable symptoms when one fourth or more of the total calories of the diet came from protein. Experimentally, Hoobler found that he secured the best retention in growth when 7 per cent of the total calories came from protein. In human milk about 9 per cent of the calories are in the form of protein. Sherman has sum-

marized our present knowledge thus: "If then, the full-grown man and the child at the time of most rapid growth each requires but 10 per cent of his calories in the form of protein, it seems probable that this proportion is also sufficient for any intermediate age, if the diet is of ample fuel value and the protein is of the right kind."

Practically, it is not possible to keep the protein as low as 10 per cent of the total calories and still observe the rule of a quart of milk a day. There seems to be no reason why conditions for growth need be less favorable when the protein calories constitute as much as 15 per cent of the total calories. A liberal supply may be turned to good account in periods of unusually rapid growth. The yield of protein from children's diets per kilogram of body weight, at the 10 per cent and the 15 per cent levels, is shown in the following table:

Protein Allowances for Children

Age Years	Calories per Kg.	Grams of Protein per Kilogram of Body Weight	
		At 10 Per Cent Level	At 15 Per Cent Level
1	90	2.2	3.5
2–5	80	2.0	3.0
6–12	70–60	1.7–1.5	2.6–2.2
13–15	60–50	1.5–1.2	2.2–1.9

From this table it is apparent that an allowance of 15 per cent of total calories in the form of protein calories gives the growing child at all ages a surplus per kilogram of body weight of from three fourths of a gram to one and one third grams above probable requirement, and any intermediate value should be adequate when the proteins are of good quality and the diet as a whole meets all other nutritive requirements.

The Protein Requirement of Adults

From what we have learned of the great diversity in amino acid content of different proteins, we shall not be surprised to find that when the final assortment from a meal has en-

tered the blood stream and the cells of the tissues have begun to take up the particular kinds of amino acids which are required for their individual needs, there may be an oversupply of some and a scarcity of others. One cannot build a protein containing 22 kinds of amino acids from an assortment in which two are completely lacking, any more than one can make a dress with cloth but no thread. Nor can one build a protein containing many lysine radicals from an assortment which has very few, any more than one can make a garment from one yard of cloth when the pattern calls for five, even though one had 100 spools of thread.

Any amino acids left over in the blood stream after the different cells have taken out the ones which meet their several needs become available for use as body fuel, just as the odds and ends of timber from the building of a house may be later turned to account in the fireplace. When amino acids are burned for fuel they are deprived of their nitrogen (deaminized) and reduced to compounds containing only carbon, hydrogen, and oxygen, which burn like sugar and fat. The nitrogen, being of no use as fuel, is converted into a relatively harmless soluble substance, urea, and this is withdrawn from the blood by the kidneys and excreted in the urine. A small part of the nitrogen never gets completely changed into urea, but escapes as ammonia. Any surplus protein is promptly burned up. We have but little power to store protein against future need as we can carbohydrate or fat. The more we eat the more we burn, and urea excretion becomes a rough measure of the amount of protein used as fuel.

The two functions of protein, as body building material and as a source of energy, thus fit into one another and it is impossible to tell in advance exactly how much of the protein eaten will serve each purpose. The most practical way to study the quantity of protein required is by the feeding of animals, noting just how much must be fed to sustain life without growth, and how much must be added to insure normal growth; or by chemical studies of the nitrogen

balance; i. e., the amount of nitrogen in the urine and the feces balanced against the amount in the diet.

The Effect of Fasting on Protein Output

In studying protein requirement, it is simpler to consider first the nitrogen requirement of the healthy adult, uncomplicated by the phenomena of growth. At first thought, one might consider it possible to determine nitrogen requirement by study of the nitrogen output of a fasting individual. But here, again, several new factors appear. The amino acids needed by the cells of relatively important tissues will be drawn from small reserves of "floating" protein or from less important tissues; and the excretion of those nitrogenous compounds always being formed in active cells (such as uric acid) and in muscle cells (such as creatinine) will continue while life exists. But in the absence of food, protein will be deprived of its nitrogen and converted into sugar (glucose) to keep up the supply of glucose normal to the blood and essential to the burning of body fat for fuel. Fifty-eight per cent of the weight of the protein may thus turn to glucose and be burned along with fat for fuel, or serve as the sole source of fuel when body fat is exhausted. The nitrogen output of the fasting man is raised, then, because he uses protein for fuel, as well as for constructive purposes.

The Minimum Protein Requirement

To obviate use of protein as fuel we must feed carbohydrate, or carbohydrate and fat together, in sufficient amounts to cover the energy requirement. When we do this, we find the nitrogen output falling below that in fasting and amounting to only 2 or 3 grams per day (corresponding to 12 to 18 grams of protein), as against an output of about 10 grams of nitrogen (62.5 grams of protein) in the early stages of fasting.

But even this is not the whole story. Feeding a diet ample in calories and containing protein equivalent to 2 or 3 grams of nitrogen, we might expect to get our fasting

subject into nitrogen equilibrium. Yet only under one condition can we do so; that is, when the amino acid supply taken is exactly like the amino acid assortment needed at that moment by the cells, so that there are no leftovers to be used up as fuel. Martin and Robinson, two English investigators, and Lauter and Jenke, two German workers, tried very earnestly to secure nitrogen equilibrium on the same amount of nitrogen as they found to be excreted on a nonnitrogenous diet meeting energy requirements. With milk and with meat they came close to equilibrium, but never succeeded in reaching it. With wheat flour or whole wheat bread there was a considerably higher nitrogen output than on the nonnitrogenous diet.

By increasing the quantity of protein a little (22 grams of protein for a man weighing 70 kilograms) and still keeping the energy balance, we can get equilibrium quite easily with milk alone, white bread alone, or bread and milk in equal parts, and also with meat. Slightly more (35 grams per 70 kilograms) is needed with cornmeal or oatmeal and a very little milk as the sources of protein. Over 100 nitrogen balance experiments where the protein intake was kept low, various simple mixed diets being used, have been critically studied by Sherman, who concludes that on the average 0.6 gram of protein per kilogram (42 grams for 70 kilograms) may be regarded as sufficient to maintain equilibrium. This is the minimum protein requirement for adults.

Best Amount of Protein

Since protein in excess of requirement is readily burned as fuel, there is no particular reason for trying to keep the amount in the daily diet down to the minimum. It is actually difficult to do so, on account of the richness in protein of many of our commonest foods. Moreover, considering the somewhat uncertain amino acid assortment from a diversified diet, and the likelihood of fluctuations in completeness of digestion, it would not be wise to adopt a minimum standard for practical living.

The real question, then, is not how little protein do we need, but how much is it desirable to indulge in? Mendel has shown that rats can be brought to maturity with 75 per cent of their calories derived from protein. The Eskimo eats two and three times as much protein as most dwellers in the temperate zone, and a vigorous young tribesman may eat as much as nine pounds of meat daily when seals are plentiful. In the tropics, however, the consumption of protein is often not more than half that of the temperate zone. Professor Krogh, of the University of Copenhagen, estimates that the calories in the three types of diet are distributed somewhat as in the table below. If men can adapt themselves so readily, does it make any difference how far above requirement we set our practice?

Distribution of Calories in Diets of Different Races

	Weight Kg.	Protein Gm.	Total Calories	Distribution of Calories Per Cent		
				Protein	Fat	Carbohydrate
Eskimo	65	282	2,604	44	48	8
Bengali	50	52	2,390	9	10	81
European	70	118	3,055	16	17	67

In answering this question, we must remember that the Eskimo eats meat because he has to. An Eskimo family of four easily consumes 4,000 pounds of meat in a year, but bread, fresh vegetables, fresh fruit, salt, and sweets are lacking. The children suck frozen eggs as the children of America suck lollipops. There is very little carbohydrate food to be had—a reindeer stomach now and then as a delicacy, its contents partly digested moss; lichens; or perhaps the skin of a young whale, rich in glycogen—so the Eskimo must manufacture from his protein the glucose which enables him to burn fat satisfactorily. Furthermore, in the Arctic winter, when "in semi-darkness the Eskimo family sits fully dressed upon the bed platform listening to the roar and whizz of wind and drifting snow past the trans-

lucent windows of seal intestines," [1] the extra heat produced by the stimulating effect on the energy output of a high protein diet helps to create comfort in that inhospitable climate. In warmer regions there does not seem to be any good reason for such generous use of protein, when carbohydrate food is everywhere obtainable and much the cheaper and when extra heat production from food frequently means so much more heat to get rid of lest it cause real discomfort. To what extent climate influences the ease with which the kidneys eliminate nitrogenous waste is not known, but there does not seem to be any good reason for putting an unnecessary load upon them, any more than there is for straining one's back to lift a trunk just to see how far one can tax his muscles. We have no easily applied measure of kidney endurance and, inasmuch as their fitness is indispensable to well-being, it would seem common sense to undertax rather than overtax them.

Protein does not exert any marked stimulating effect on heat production when it constitutes a relatively small proportion of the total calories; i. e., not over 10 to 15 per cent. Assuming the average daily energy expenditure of a sedentary man to be 2,500 calories, 10 per cent or 250 calories in the form of protein would be equivalent to 62.5 grams of protein, equal to 0.9 gram of protein per kilogram, while actual requirement is, as we have seen, about 44 grams per day or 0.6 gram per kilogram. Hence, an allowance of 10 per cent of the total calories in this case means 50 per cent more than requirement, which should allow for varying efficiency of proteins of different amino acid make-up, provided some proteins of high efficiency, such as those of milk, eggs, or meat, are included in a digestible mixed diet.

Muscular Work and Protein Requirement

Although it is possible for muscular work to be done exclusively at the expense of protein, what really happens is

[1] Macmillan, D. B. "Food Supply of the Smith Sound Eskimos." *American Museum Journal*, March issue, page 172 (1918).

that the protein so used is first deprived of its nitrogen and thus put on a par, so to speak, with the other fuel foods, carbohydrate and fat. It is as if one should undertake to make a fire with boards full of nails. The boards would burn like any others, but the nails would add nothing to the fire. The early conception of the relation of protein to muscular work was quite erroneous. Liebig, the great pioneer in biochemistry, having discovered the significant fact that protein gives rise to nitrogenous substances which appear in the urine and feces, and having suggested that urea might be a measure of protein metabolism (1840), conceived the idea that in muscular contraction muscle substance was destroyed and could only be replaced by protein—"dead meat and blood must be converted into living flesh and blood." [1]

Before Liebig's death, however, it was shown by Bischoff and Voit (1860) that this view was wrong. They fed meat to dogs under a variety of conditions, collecting and analyzing the urine, and found that the more protein the dog ate the more nitrogen there was in the urine; that it was the character of the diet rather than the amount of muscular work which caused changes in the protein metabolism. This concept was put to the test in 1860 by two of Voit's pupils, Fick and Wislicenus. They undertook to discover just how much protein was used in a strenuous excursion up the Faulhorn, a mountain over 6,000 feet high, and demonstrated conclusively that muscular work is done almost entirely at the expense of carbohydrate and fat when these are available. Eating only nonnitrogenous food and keeping account of all nitrogen excreted in the mountain adventure, these young men compared the amount of protein metabolized with the work actually done and found that less than half the fuel burned was derived from protein.

Years later a far more accurate experiment of Atwater's showed more clearly the influence of work on nitrogen excretion. Several persons were studied in the respiration

[1] Cited by Lusk, Graham. Barker's *Endocrinology and Metabolism*, page 48. D. Appleton and Co. (1922).

calorimeter for many days, first at rest and then at work. In the rest experiments they metabolized 1.51 grams of protein per kilogram; when they worked hard enough to double their heat production they did not raise their nitrogen output at all, as it averaged 1.49 grams per kilogram. Under some circumstances the amount of protein metabolized during muscular activity may be slightly higher than during absolute rest, but if the protein intake amounts to as much as one gram per kilogram, as it usually does in a wholesome mixed diet, any such increase due to muscular exertion is more than covered by an intake which is nearly 100 per cent above requirement. In severe muscular exercise, the foodstuff needed to prevent exhaustion is not protein but carbohydrate.

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CHAPTER VIII

MINERAL ELEMENTS AND WATER AS BODY BUILDING MATERIAL

Section i

MINERAL ELEMENTS

The mineral elements which are essential components of the human body will be realized better, perhaps, if we make a list showing the approximate amount of each present in the organism:

Mineral Elements in the Human Body

Element	Amount in a 70 Kg. Man Gms.
Calcium	1,050
Phosphorus	700
Potassium	245
Sulfur	175
Sodium	105
Chlorine	105
Magnesium	35
Iron	2.8
Manganese	0.21
Iodine	0.028
Cobalt, Copper, Silicon	Very minute quantities

Traces of other elements, e. g., boron, arsenic, zinc, aluminum, fluorine, and nickel, have been reported but it is doubtful whether these are essential to body structure. They are so prevalent in food and in the dust about us, that small amounts easily lodge in the tissues.

Upon food we depend for a supply of all needed mineral elements, just as we depend upon it for the various amino acids which are built into the body proteins. Pure carbohydrates and fats furnish none. Upon protein we depend

for our sulfur, found chiefly as an integral part of the amino acids cystine and methionine. Just as proteins vary in their proportion of cystine they vary also in their yield of sulfur, some, such as lactalbumin, being very rich and others, as gelatin, lacking it entirely. Food iron is frequently combined with protein, not only in the hematogen of egg yolk and the hemoglobin of blood but also in food materials which we do not usually consider rich in protein, such as the green parts of plants and outer coats of grains. While certain proteins are rich in phosphorus; e. g., the vitellin of egg yolk and the casein of milk; and certain ones yield calcium, the most important being casein, we are not dependent upon proteins for either phosphorus or calcium.

With the exception of sodium and chlorine, which we get chiefly combined as common table salt (sodium chloride), the mineral elements of the diet are drawn from a great variety of sources and only tables showing the chemical composition of food materials will give satisfactory information in regard to their distribution.[1]

Mineral Elements in Body Structure

Quantitatively the mineral elements most prominent in the body are calcium and phosphorus. They chiefly are responsible for the rigidity of the bones and teeth. In bones with marrow, the mineral matter is about two fifths of the total dry weight; in bones without marrow, about three fifths; and of this total mineral content about 85 per cent is calcium phosphate and 10 per cent calcium carbonate. Altogether, approximately 99 per cent of the total calcium and 90 per cent of the total phosphorus of the body are in the skeletal tissues, and serve to maintain the framework whose value we most appreciate when we see the effect on health and beauty of poor teeth or of a disease like rickets, in which the mineral deficiency of the bones may result in a hollow chest and poorly developed lungs, to say nothing of the unattractiveness of bowlegs, knock-knees, or flat feet.

[1] See Appendix, Table I.

The structure and the functions of the human body cannot be well understood without appreciation of the fact that the cell, a microscopic mass of protoplasm, is a unit endowed with all the attributes of life.[1] The egg cell divides into two daughter cells, which in turn divide each into two others, until there are finally billions and billions of cells, differentiated in the process of development for various functions; some for building skeleton, others for nerves, others for the digestive system, etc. In a cubic inch of normal human blood there are said to be as many as 70 billion cells, red and white, all equipped for special chemical work.

The life of the cell is governed by a minute but highly organized mass of protoplasm called the nucleus. It consists of a net-like framework whose meshes are filled with a special kind of protein called nucleoprotein and whose threads entangle granules of chromatin, consisting of highly complex proteins containing iron. Upon the integrity and the efficiency of the chromatin substance of the nucleus depend the nutrition, growth, and reproduction of the cell and hence the very life of the organism as a whole. A diminution or withdrawal of the supply of iron, therefore, interferes with fundamental nutritional processes.

The proteins of the cell nucleus, nucleoproteins, are distinguished by the fact that they contain phosphorus as an integral part of their structure; hence phosphorus, like iron, is intimately associated with the fundamental processes of nutrition, sharing in the control of cell activities.

The body of the cell, the cytoplasm as it is called, contains, in addition to protein, mineral salts and water, another substance called lecithin, allied to the fats but having phosphorus as an indispensable element in its composition. Lecithin helps the cell to connect with its environment, to absorb nourishment, eliminate waste, or discharge some product of its own chemical activity for the benefit of other parts of the organism.

[1] For an adequate description of the cell and its relation to body structure as a whole, recourse must be had to standard works on biology.

Among cells differentiated for special function are the red corpuscles of the blood, which are the carriers of oxygen to all the tissues and the removers of carbon dioxide arising from the combustion of body fuel. Their power to transport these gases depends upon an iron-bearing protein, hemoglobin, and any serious diminution in its amount is accompanied by increased respiration and accelerated heart action in an effort to compensate for the lessened carrying capacity of the blood. It is just as if a chain pump which could easily deliver a certain amount of water per second if the handle went up and down once every half minute had half its buckets removed. Then to make the same water delivery the pump handle would have to go up and down twice as often.

Phosphorus and iron are as essential to every living cell as nitrogen. On this point we may quote two authorities on the metabolism of these elements. Forbes, the successor of Armsby as director of the Animal Nutrition Laboratory at the Pennsylvania State College, says in regard to phosphorus: "Among the several inorganic elements involved in animal life phosphorus is of especial interest. No other one enters into such a diversity of compounds and plays an important part in so many functions. Structurally, it is important as a constituent of every cell nucleus and so of all cellular structure; it is also prominent in the skeleton, in milk, in sexual elements, glandular tissue and the nervous system." [1] And Sherman, upon whose own researches regarding iron our knowledge of iron requirement largely rests, says in regard to this element: "Iron stands in the closest possible relation to the fundamental processes of nutrition, being an essential constituent both of the oxygen-carrying constituents of the blood and of the substances which appear to control the most important activities within the cell." [2]

[1] Forbes, E. B., and Keith, H. M. *A Review of the Literature of Phosphorus Compounds in Animal Metabolism*, page 11. Ohio Agricultural Experiment Station, Tech. Bull. No. 5 (1915).

[2] Sherman, H. C. *Iron in Food and Nutrition*, page 7. U. S. Department of Agriculture, Office of Experiment Stations, Bull. No. 185 (1907).

The other mineral elements are found variously distributed in the body, chlorine occurring chiefly in the gastric juice; sodium in the blood and other fluids, combined with chlorine as sodium chloride (common salt); potassium, most abundantly in the protoplasm of muscles and various organs; magnesium, chiefly in the bones but also in muscles and a little in blood; silicon, in bones and teeth; iodine, in the thyroid gland and its product, thyroxin. Copper is very closely associated with iron in animal tissues. It is found in high percentage in the liver, especially of the newborn. Although it does not appear to enter into the structure of hemoglobin, it is in some way essential to its formation. While these elements contribute to the composition of the body, they function more prominently in the regulation of body processes and these regulatory functions will be discussed in Chapter IX.

Section 2

WATER

When a rubber water bottle is full of water, one is quite well aware that the water is there, even though the stopper

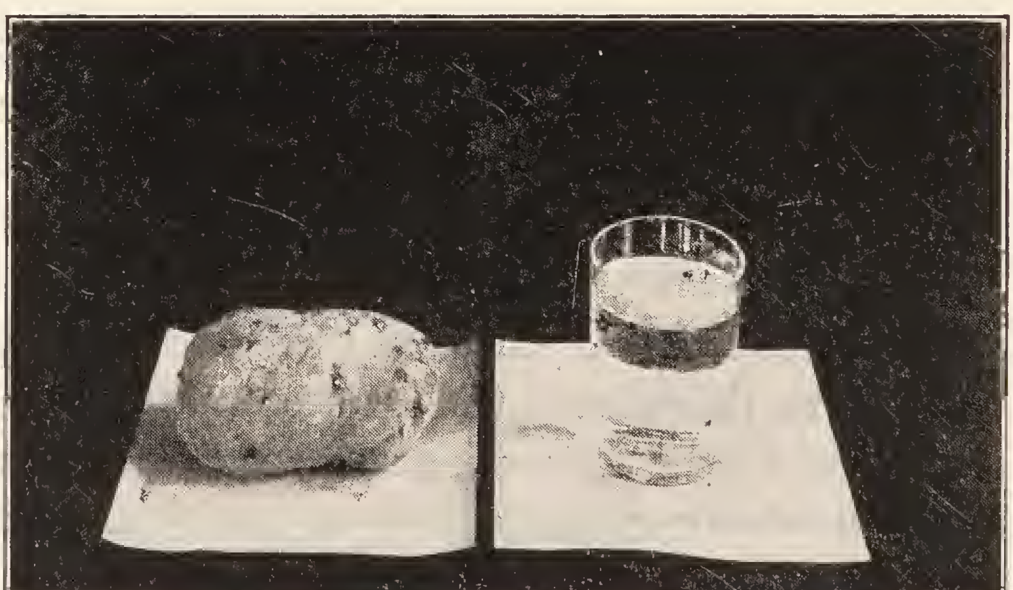


Fig. 39.—A Half-Pound Potato Contains Nearly a Tumblerful of Water.

holds every drop inside and the outside is perfectly dry; but how many realize that a potato skin, neatly incasing the useful tuber in a dry covering, also holds water like the

rubber bottle? We do not realize the water in the potato as we do in the bottle because it is held in the cells; but when we break the cell walls, as in grating a raw potato, we can squeeze out a surprising amount. It is the same with the body of a man. Muscles, liver, and kidney hold as much water in proportion to their weight as does the potato; brain tissue holds more; and even bone, proverbially dry, is more than one third water. Altogether, two thirds of the adult human body is water.

Water is essential to the constitution of protoplasm. No cell functions when it is absolutely dry, and most cells must be constantly bathed with fluid, in order to do their

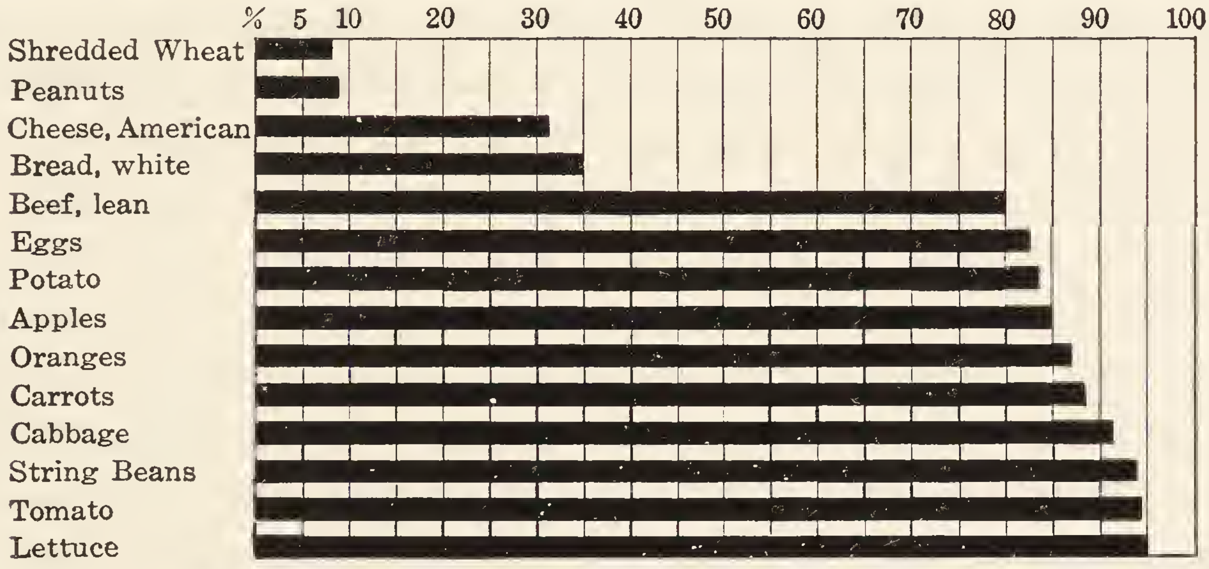


Fig. 40.—Relative Amounts of Water in Some Common Food Materials.

work. Furthermore, the cells depend upon having their food transported to them by the water route (the blood), a demand which alone requires about ten pounds of water constantly in circulation. The cells also depend upon having their waste products flushed away, so there must be waste-bearing water (urine) while there is life. The surface of the lungs must be kept moist or there can be no intake of oxygen or riddance of carbon dioxide.

Water is so commonly taken in response to the feelings of thirst that we ordinarily think little about our water supply, save to be sure that it is sanitary and refreshing. But we also get more or less water in food, as even the driest cracker is not absolutely water free. The amounts in some common foods are indicated in Fig. 40.

A certain amount of water is produced within the body by the combustion of the fuel foods. A similar production of water may easily be demonstrated by setting a cold flat iron on a gas burner. Before the flame has had time to warm the iron the water of combustion from the burning gas condenses on the iron, often making it perceptibly wet. Later on, the heat of the iron converts the water into vapor and it is no longer perceived. So in the body, the oxidation of 100 grams of fat results in the production of 107 grams of water, and the oxidation of 100 grams of protein, of 41 grams of water. Benedict calculated that Levanzin, the subject of the thirty-one day fast, produced on the twenty-first day by combustion of his own body substance 341 grams of water. This metabolic water is useful for the distribution of nutrients, making changes in concentration within the cell which facilitate movement of substances into the cell.

Many varieties of insect have nearly all their water needs met by this metabolic water, subsisting on food containing less than 10 per cent of water and never taking a drink. For animals in hibernation, it is sufficient for several months. The dog requires no other water if he eats plenty of meat. Dogs have not as high water loss as man because they do not perspire.

DuBois finds the average loss of water from lungs and skin in the normal resting man to be 680 grams per day, if the temperature is 23° C. (73.4° F.) and the humidity medium. Benedict and Milner account for the water intake and output of a man for a day as follows:

Intake		Output	
Drink	1,950.00 grams	Feces	191.30 grams
Food	2,972.43 "	Urine	1,089.20 "
		Respiration and perspiration	3,929.73 "
	4,922.43 grams		5,210.23 grams

The water content of the body is subject to considerable fluctuation. Benedict and Joslin report a marathon runner who lost 8.5 pounds in three hours and a football player who lost 14 pounds in one hour and ten minutes, of which

13.75 pounds were calculated to be water. Not only "sweating out" but also certain changes in diet affect the water content of the body; for example, when the body changes from a strictly carbohydrate diet to one of fat or protein exclusively there is a considerable loss of water which will be regained upon resumption of the carbohydrate diet. Thus Benedict and Milner in a six-day experiment gave first for three days a diet having 66 per cent of its calories in the form of carbohydrate. On this the subject gained 165 grams of water, but part of this replaced other body substance, as the weight gain was only 61 grams.

There are, then, three important sources of body water:

(1) Water taken as a beverage or in other liquids.

(2) Water contained in solid foods, especially fruits and vegetables.

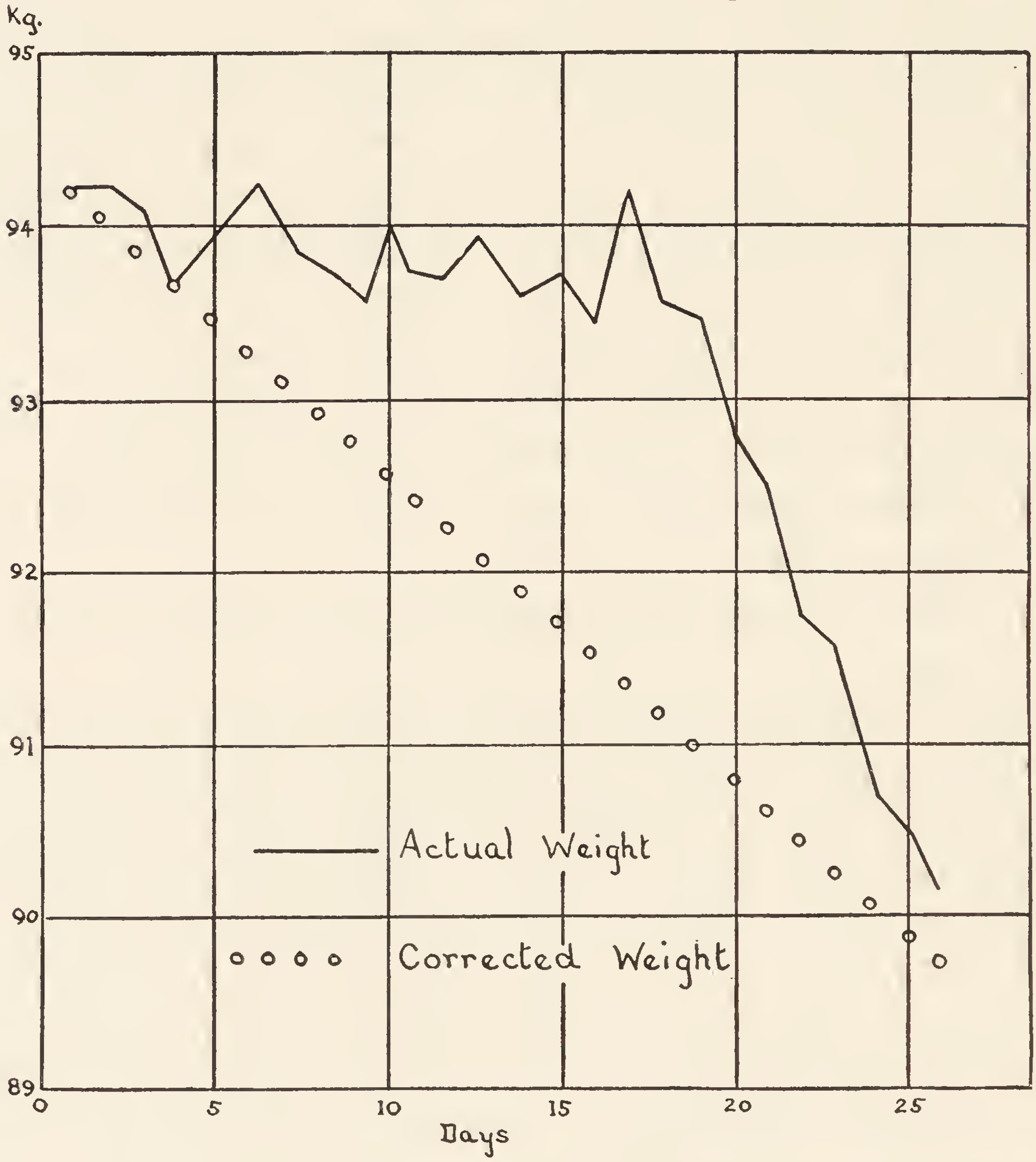
(3) Water formed in the tissues in combustion of the fuel foods.

The normal avenues for water loss are the skin, the respiratory passages, the alimentary tract, and the kidneys. Any considerable loss or storage of water usually results in a change in body weight. But in undernutrition water may be stored in the tissues in place of fat, and conversely, in obesity fat may replace water. Hence an underweight may increase his food intake with real advantage even though there be no visible gain in weight at first; and an obese person may be disappointed that reduction in food intake does not bring about an immediate loss of weight, owing to the replacement of any body fat burned by water.

An interesting study is reported by Newburgh at the University of Michigan Hospital.[1] A girl of fourteen who weighed 207 pounds was established in the metabolism laboratory, where no food was available except what was brought to her by the attending nurse. Her daily food allowance was 1,223 calories less than her daily energy output. For over two weeks she showed no loss in weight,

[1] Newburgh, L. H., and Johnson, M. W. *The Exchange of Energy between Man and the Environment,* page 89. Charles C. Thomas (1930).

although during this time she had burned up, as shown by actual measurement of her energy output, 2,896 grams (over six pounds) of her own body substance. As the study



(*Courtesy of Dr. L. H. Newburgh*)

FIG. 41.—The changes in weight of an obese girl on a reducing diet. She retained water for over two weeks, and during this time showed no loss in weight although combustion of body fat was going on all the time. Later the water was excreted and her weight fell. The line of circles shows the rate at which loss would have occurred had there been no water retention.

progressed, it became evident that during this period she was storing water at the same time that she was burning off superfluous fat. In a second period of ten days, she lost nearly nine pounds of weight, of which only about 3½ pounds could be accounted for by the calories spent during this time. The rest of the loss was water.

Figure 41 shows her actual changes in weight and also what she would have weighed if there had been no extra water retained.

In health the water balance is easily maintained by a liberal water intake. In disease the disturbance of the water equilibrium may be serious and call for special measures to bring about normal conditions. The rôle of water in the regulation of body processes will be discussed in Chapter IX.

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CHAPTER IX

MINERAL ELEMENTS AND WATER AS REGULATORS OF BODY PROCESSES

Section I

MINERAL ELEMENTS

For the purposes of the present chapter we may advantageously picture the cells of the body as the citizens of a great metropolis. As individuals, each has a private independent life of his own; yet each life is modified by sharing in the activities of some group. Just as citizens come together to work in the same shop or to participate in the enterprises of some club, so cells are massed in tissues and organs to perform some special service impossible to one alone. Furthermore, in addition to individual and group activities, all share in the larger life of the whole. And just as citizens all over a city use the same water and gas mains, the same electric wires for light and telephone, and the same mail service, so cells all over the body derive nutriment from the common blood stream and receive oxygen by means of the same respiratory system. In either case individuals, and even large groups, may never meet one another; yet the community life is maintained through "regulations" which direct their actions and prevent one individual or group from prospering at the expense of others, or the aggregate doing injury to any one portion.

There are found in food certain substances which figure prominently in the coördination of the functions of nerves, glands, muscles, etc., and enable the body to use its available fuel and building material to the best advantage. These regulating substances may be grouped in three main divisions: mineral elements, water, and vitamins. Mineral elements and water will be discussed in this chapter.

Some Ways in Which Mineral Elements Function

We have already seen that chemical elements which may enter into the structure of the body in very minute quantities are highly important for the maintenance and growth of the cells. In the regulation of body processes, the amount of an element present in the organism gives no clue as to its significance in the coördination of cell functions. Each element has its own special part to play; two which may be closely related chemically cannot exchange places and may in some of their functions be actually antagonistic to each other. Inasmuch as the rôle of the mineral salts in vital processes is a matter of their physicochemical relationships, any detailed discussion of their functions leads far into the fields of chemistry and physics, and is beyond the scope of this book. No attempt will be made to do more than discuss briefly some of the more obvious ways in which the minerals aid in the regulation of body processes.

In the first place, minerals influence the contractility of muscles. If a muscle is removed from the body and put into a solution containing a suitable mixture of pure salts (particularly calcium, sodium, and potassium chlorides) it will, when stimulated, contract as it would in the body. But if it is put into distilled water (which contains no such salts) it will not respond when stimulated. Again, if the muscle is put into a solution containing the sodium and potassium mentioned above, but not the calcium, it will fail to respond; but when calcium is again added in suitable amount to the solution it will respond as at first. Thus the dependence of the muscle upon calcium may be demonstrated in the laboratory. It may also be demonstrated by the use of a frog's heart, which can be made to beat or stop as calcium is present or absent from a solution in which the organ has been suspended. So we say the muscles of the heart depend for their rhythmic beat upon the nature of the salts in the fluids which bathe them.

In the second place, minerals determine the irritability

of nerves. Just as a muscle will not contract normally if suspended in distilled water, so a nerve similarly placed will fail to respond to any stimulus, but when bathed with a suitable salt solution will behave in the normal manner. All the organs regulated by the central nervous system depend for the integrity of their functions not only upon the presence of calcium, potassium, and sodium in the fluids within the nerve tissues, but upon their presence there in just the right proportions.

In the third place, minerals control the movement of liquids in the body. Digested food materials must pass freely from the intestine into the blood stream without any blood passing back into the intestines. Also, liquids must pass from the blood into the various organs and tissues, and such a fluid as the gastric juice must be derived from the blood and poured into the stomach. Furthermore, the waste matter of the cells taken away by the blood must be withdrawn from it by the kidneys and discharged in the watery solution which we call urine. It is due to interactions between mineral elements that the cells can bring these things to pass.

Another function of mineral elements is to assist in the coagulation of the blood. Any wound, however slight, would threaten death by bleeding had we not this interesting protective mechanism, whose value we appreciate only when we learn of certain persons known as "bleeders," whose blood does not readily clot, even after a pin prick. Calcium is an important factor in the coagulation process.

Mineral elements are essential also to the digestive processes. For example, in the stomach, the gastric juice owes its characteristic acidity to hydrochloric acid, upon which the activity of pepsin in digestion depends. In the small intestine, other mineral salts make the secretions alkaline, favoring the digestive processes there, especially the digestion of fat.

Another important function is to keep the blood neutral—neither acid nor alkaline. Here phosphorus (as phos-

phoric acid) and sodium (as bicarbonate) act as buffers, which means that, when they are present in a solution, considerable amounts of acid or alkali may be added without showing any effect, for they change so as to dispose of the acid or alkali as such and keep the solution neutral. The situation is somewhat like that of two children of unequal weight at each end of a teeter; they solve the difficulty of not being able to move up and down on account of their weight inequality by placing a third child in the middle to serve as a buffer; i. e., to move first toward one child and then toward the other, thus adding his weight where it is needed at the moment.

Mineral elements take part in the transport of oxygen from the lungs to the tissues and of carbon dioxide from the tissues to the lungs which alone makes possible the continued combustion of fuel foods. The power of the iron-bearing hemoglobin of the blood to combine under certain conditions with oxygen and under other conditions with carbon dioxide is fundamental to the process of respiration.

As the minerals enter into the composition of every living cell, they determine the vital processes of oxidation, secretion, development, and reproduction. Phosphorus and iron, indispensable to every active cell, as shown in Chapter VIII, are outstanding examples of such controlling elements.

Mineral elements are essential to the structure of certain complex chemical compounds which profoundly influence the course of metabolism. One conspicuous example is iodine, an element found only in the thyroid gland and its product thyroxin, which have been referred to in Chapter IV as powerfully influencing the energy metabolism. But this is not all. Without iodine for the proper functioning of the thyroid, normal growth in the young and the maintenance of health in the adult are impossible. The influence on development is strikingly shown in the case of tadpoles; ordinarily they require three weeks to change into frogs;

given thyroid, the metamorphosis begins in a few days and is completed so rapidly that there is no time for growth in substance along with the loss of tail and formation of legs, so that the result is pygmy frogs. In the human adult loss of thyroid function results in changes in skin, hair, facial contours, and other signs that a controlling mechanism is out of order.

Requirements for Mineral Elements

The body is constantly losing some of each mineral element. It becomes necessary to replace the loss through diet, or health will not be maintained. For the adult, whose tissues are fully formed, it is only necessary to make good the "wear and tear"; for the growing organism there must be, as in the case of protein, an additional "growth quota" to foster the construction of new body substance at a proper rate.

In order to administer the diet intelligently, we need to know as much as possible about the requirements for various mineral elements, both in childhood and adult life. For some elements, as calcium and phosphorus, the amount needed daily is relatively large, and on this account there is possibility of serious shortage unless food is chosen with discrimination; for others, as iron, the portion needed day by day is very minute, but the quantities in food materials are also minute, and an intake below the optimum is likely to occur if the matter be left entirely to chance. Practically we shall find that if the requirements for calcium, phosphorus, iron, and iodine are definitely met there is little likelihood of the other mineral elements being inadequately furnished, since the foods which supply the former will at the same time provide the latter.

The Requirement for Phosphorus

Phosphorus is indispensable for all active tissues of the body, being concerned in cell multiplication and cell movement and the maintenance of the proper liquid content of the tissues. It also plays an important part in regulating

the neutrality of the blood and is essential at one stage of the chemical change through which carbohydrates are oxidized and their energy liberated at just the rate demanded by the needs of the organism.

Phosphorus leaves the body partly in the urine and partly in the feces; the relative amount leaving by each path largely depends on the composition of the diet. When food rich in calcium is eaten, more phosphorus is excreted through the feces than when little calcium has been taken. Sherman, from consideration of extensive work in his own and other laboratories on the phosphorus requirement of adults, says: "We are probably justified in concluding that we now know the phosphorus requirement with about the same probable accuracy that the protein requirement is known, and that about one-fortieth to one-fiftieth as much phosphorus as of protein is required in the maintenance metabolism of man." [1] This gives for the adult an average of 0.88 gram per 70 kilograms of body weight.

Since it is impossible to estimate individual requirement with absolute precision under ordinary living conditions, and equally impossible without laboratory experiments to estimate intake exactly, the amounts in food being subject to considerable fluctuation, it is only prudent to set a practical dietary standard considerably higher than the actual amount needed for maintenance. It seems very moderate to add 50 per cent as a "contingency fund" or "factor of safety." This would make a dietary standard of 1.32 grams of phosphorus per man per day, equivalent to 0.019 gram per kilogram of body weight. For adults of ordinary activity 0.044 gram per 100 calories per day will cover the ordinary requirement.

The Phosphorus Requirement of Children

Because phosphorus is essential to all body tissues, the growth of new body substance involves the retention of a

[1] Sherman, H. C. "Phosphorus Requirement of Maintenance in Man." *Journal of Biological Chemistry*, Vol. 41, page 173 (1920).

certain amount, just as it does a storage of protein. The greater part of the retained phosphorus is deposited in the bones along with calcium, as calcium phosphate. If conditions are not favorable for the deposition of calcium phosphate in the bones, we have the disease known as rickets, which will be discussed in detail later. One of the notable advances in the study of rickets was the observation that it is characterized by a low phosphorus content of the blood. After that it was demonstrated that rickets could be produced experimentally by feeding a diet low in phosphorus. Thus the importance of this element in the diet of the young received additional emphasis. An extensive study of the phosphorus requirement of children has been made by Sherman and Hawley. They took twelve children ranging in age from three to thirteen years to a country home for convalescent mothers, where they could be supervised day and night, and kept account of all food eaten and of all excreta. Some of the children were under this close observation as long as 84 days. From analysis of the data so collected, the authors conclude that the child needs for optimum growth about one and one half times as much phosphorus as is needed by a full-grown man for maintenance. This would make the child's allowance about one gram per day which seems an excellent standard up to the age of 14 years. Allowing thereafter 0.044 gram of phosphorus per 100 calories, as in the case of the full-grown adult, will generally insure adequate phosphorus intake because of the relatively high calorie intake of children.

The Requirement for Calcium

The rôle of calcium as body building material is obvious and striking. The rigidity of the bony framework of the body is in such contrast to the softness of other tissues and is so clearly related to the presence of calcium in the bone that every one is impressed. The same is true with regard to the teeth. Not so readily apparent, but of even greater significance, is the part played by this element in the regula-

Fig. 42.—Foods Yielding about 0.044 Gram of Phosphorus.

	Grams		Grams		Grams
Lettuce	110	Carrot	139	Shredded wheat	14
Spinach	96	Milk	47	Cheese, American	6
Celery	92	Cucumbers	288	Egg	20
Beets	128	Tomato	152	Beans, Lima, dried	11
Cabbage	129				

tion of body processes. Some of the ways in which it functions have already been mentioned in discussing the general functions of minerals: viz., the control of the contractility of muscles, and particularly the rhythmic beat of the heart; the preservation of the normal response of nervous tissue to stimuli; and the coagulating power of the blood. In addition to these very important functions, calcium is a kind of coördinator among the mineral elements. As has already been said, these must be nicely balanced in order that all parts of the body may function successfully; if sodium, or potassium, or magnesium, for instance, should tend to be too much in the ascendancy, calcium is capable of correcting the disturbance which they might make, whether it be in the direction of increased or decreased irritability. Altogether, it is highly important that the organism have at all times an adequate supply of this element.

In adults, the bones become to some extent a reservoir of calcium, which can be drawn upon to replenish the soft tissues and fluids, with no damage to the bone other than the weakening consequent to withdrawal of some of the supporting calcium phosphate. But in the young there must be a liberal supply of calcium for the developing bones and teeth; any deficiency in the calcium supply, or any disturbance of the conditions under which the bone is able to store calcium, results in weakened bones, contracted thorax and pelvis, defective teeth, and otherwise stunted growth.

The calcium requirement must be studied by taking account of calcium in food, urine, and feces, in carefully planned experiments. Ninety-seven experiments of this sort, analyzed by Sherman, indicate that the calcium requirement of adults is about 0.45 gram of calcium per day. As in the case of phosphorus, there should be a "safety allowance" of at least 50 per cent more, making a dietary standard of 0.68 gram per man per day or 0.0097 gram per kilogram of body weight.

The calcium requirement of women is greatly increased by pregnancy and lactation. During pregnancy the mother must provide a store of calcium upon which the fetus draws

for the development of its skeleton. Lusk cites a study of the calcium retention of a mother and child for 23 weeks in which it was found that the mother retained only 4.2 grams, but the fetus retained 30.12 grams, or more than seven times as much. The weekly additions to the calcium of the fetus at different periods were as follows:

Week of Pregnancy	Calcium Added per Week Grams
16	0.41
21	0.43
29	2.09
40	2.09

In the last two months, during which about two thirds of all the calcium appropriated by the fetus is stored, an intake of at least one gram per day would seem desirable.

During lactation the mother has to supply for months the calcium required by a rapidly growing infant. From the average milk intake of breast-fed babies it may be estimated that the mother will furnish in her milk calcium in approximately the following amounts:

Weekly Calcium Consumption of Infants

Age Months	Calcium in Milk Grams per Week
3	1.9–2.2
6	2.5–2.7
9	2.7–3.0

Doctor Icie G. Macy, Director of Nutrition Research at the Children's Hospital of Michigan in Detroit, has made a long study of three women during the entire reproductive cycle. They were housewives from the mother's milk bureau of Detroit, which maintains a depot for supplying mother's milk to babies who specially need it. They were living in their own homes, taking care of their families, and eating their own freely chosen diets. All were able to secrete large quantities of milk and all took large quantities of cow's milk as a beverage, so that it supplied three fourths or more

of the total calcium and half or more of the total phosphorus. The total intake of both calcium and phosphorus usually exceeded 3 grams per day and ranged up to 4 grams. In first and second lactation periods these amounts were enough to keep them in calcium equilibrium for the most part, but

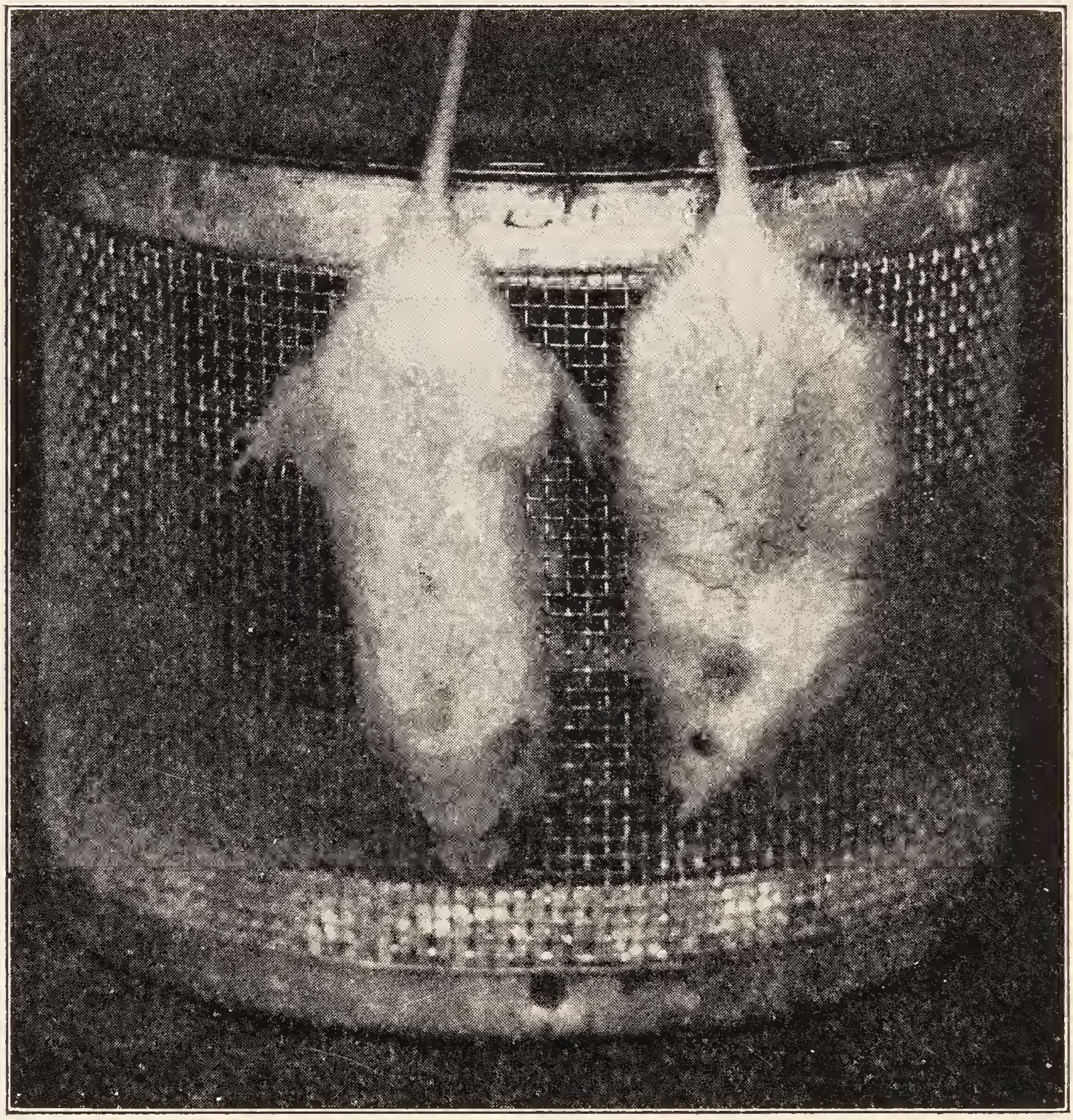


FIG. 43.—Two rats placed at four weeks of age on restricted diets and photographed at the age of sixteen weeks. The one on the left had only half enough protein, the one on the right only half enough calcium. Both weigh the same (60 grams). The control on an adequate diet weighed 216 grams at this time. Note the short, smooth fur and slender form of the low-protein rat, and the long, bushy fur and very short body of the low-calcium rat.

in third and fourth lactation periods, it became more difficult to maintain equilibrium even when cod liver oil was added to the diet to stimulate better utilization of the calcium. These women were putting their capacity for milk production to an unusually severe test, but the findings serve to

impress the importance of a very liberal calcium intake for the nursing mother, and the use of cod liver oil to aid calcium and phosphorus utilization.

The Calcium Requirement of Children

In view of the constructive and regulatory functions of calcium, it is important that the growing organism be at

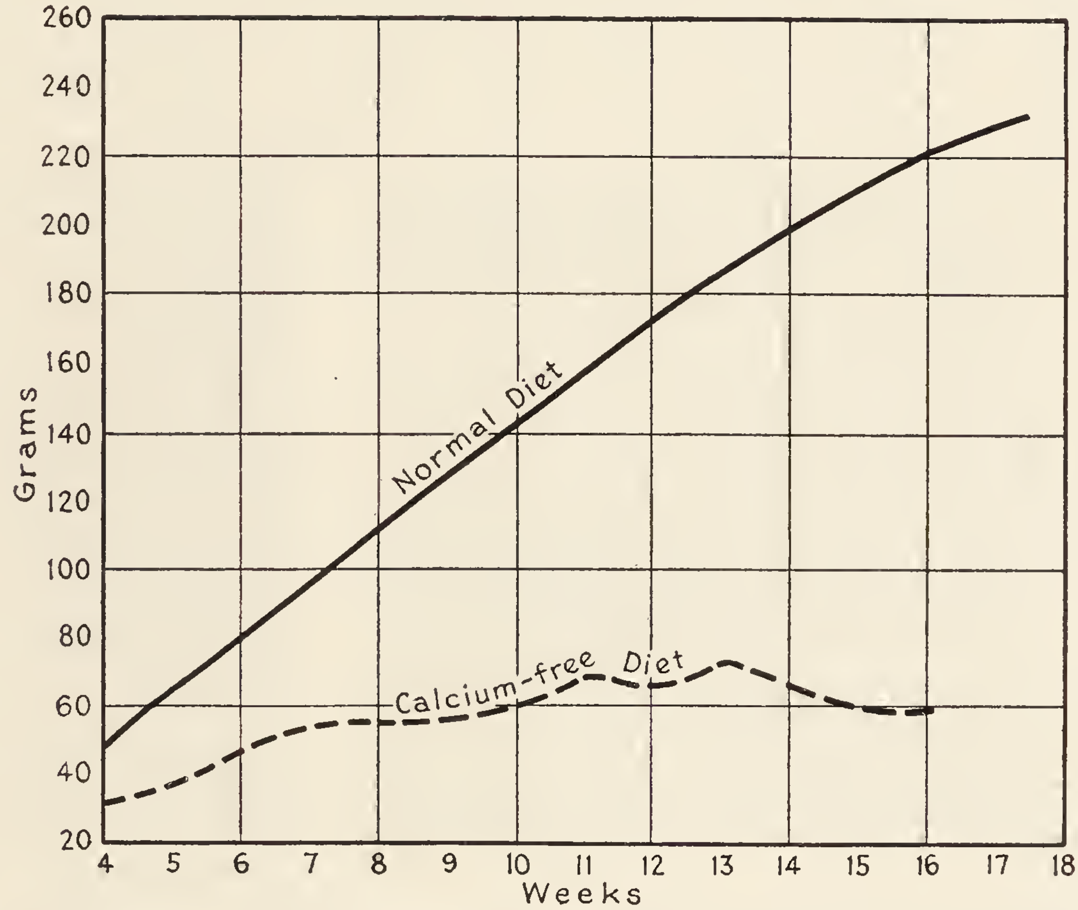


Fig. 44.—The upper line represents the growth record of a rat fed an adequate diet from weaning at the age of four weeks; the lower, that of a litter brother fed a diet lacking calcium.

all times liberally supplied with this element. The serious handicap of calcium shortage during the period of growth is readily demonstrated in experimental animals. The two rats in Fig. 43 were of the same litter, weaned from a mother on a normal diet at the age of four weeks and then put, one on a diet inadequate in protein, the other on a diet quite inadequate in calcium. That the results of a shortage of calcium are quite different from those of a shortage of protein is well exemplified by the comparison of these two animals. While both are stunted to the same degree, the low protein diet permitted more growth of the skeleton and interfered less with health, so the animal on this diet

is sleek, slim, and lively in contrast to the short, stocky, bushy, lethargic rat on the diet lacking calcium.

The effect of the lack of calcium on the rate of growth will be best appreciated by comparing the calcium-deficient animal's weight record with that of one fed an adequate diet. In Fig. 44, the animal on the normal diet weighed at the age of 16 weeks more than three times as much as did his litter brother deprived of calcium. The animal on the diet lacking calcium was not only smaller and weaker than

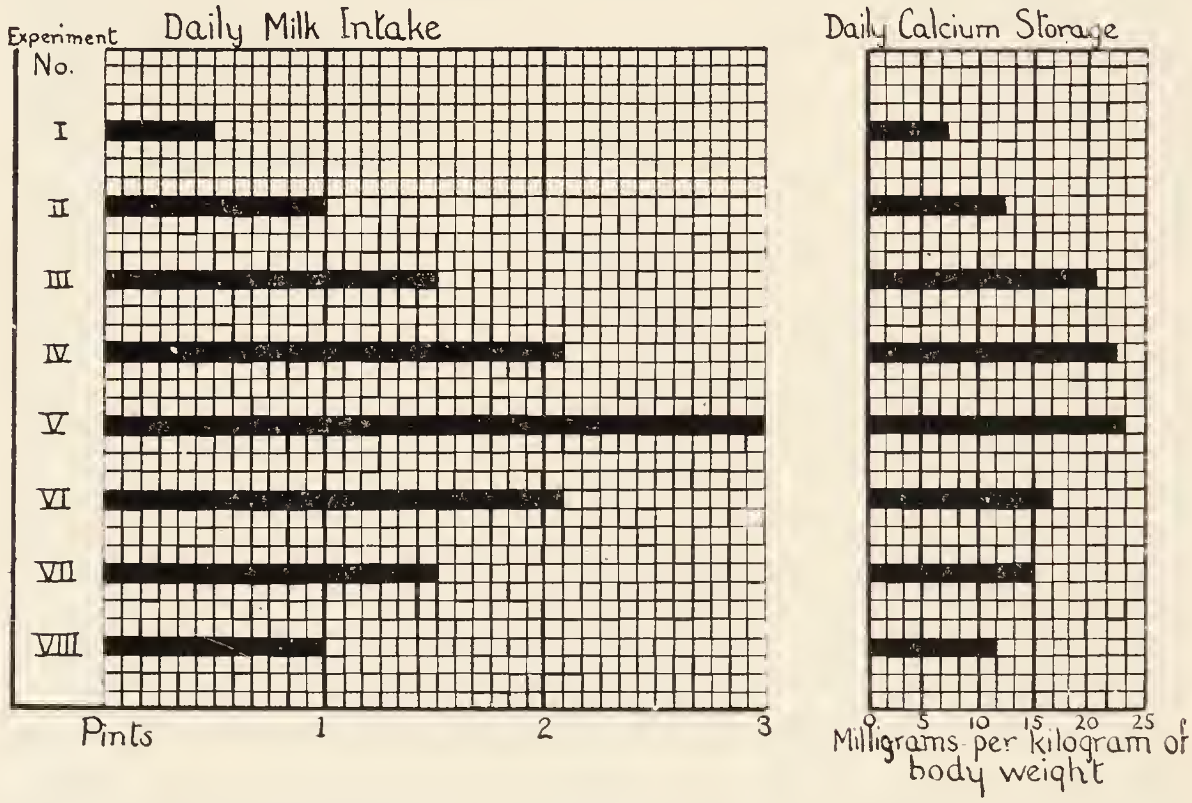


FIG. 45.—This chart shows a series of 8 experiments of 6 days each in which the calcium intake was systematically varied from period to period by changes in the amount of milk. The very definite response to increased milk intake is shown in the record of calcium storage of one of the children, a 12-year old girl.

its brother on a normal diet, but its fur was rough and thin and it suffered from nasal hemorrhages in addition to severe skeletal deformities.

Such experiments impress upon us the importance of calcium for the growing child. During the period of growth a white rat, which will have multiplied its birth weight about 70 times when fully mature, will increase the phosphorus content of its body about 150 times and the calcium content 340 times. Such figures bear ample testimony to the need for a liberal supply of calcium during the whole period of growth.

A careful study of the calcium requirement of children was made by Sherman and Hawley in 1922.[1] Altogether 417 experiments were conducted on 21 healthy children from 3 to 14 years of age. In one series, on three children, 4, 5, and 12 years of age respectively, extending over 48 days, the calcium was kept at different levels in successive periods by changing the amount of milk in the diet, in order to find out what daily allowance of milk would induce the best calcium storage. In the case of all three children the best utilization of calcium was found when approximately a quart of milk a day was included in a simple mixed diet. The relationship between the milk and the calcium storage is shown in Fig. 45.

Later studies have served to confirm these findings. Thus Dr. Genevieve Stearns and Dr. P. C. Jeans,[2] at the College of Medicine of the State University of Iowa, gave children 4 to 12 years of age diets in which the calcium was adjusted to be equivalent to that in either one pint or one quart of milk, and found as a rule considerably higher retentions with the larger calcium intake. They also noted that there was better retention when calcium and phosphorus were given together than when some source of calcium was used which did not furnish phosphorus, such as calcium carbonate, giving additional evidence of the practical value of milk, in which these two elements are both well represented.

The most striking confirmation of Sherman and Hawley's work is that of Dr. Amy L. Daniels [3] and her associates at the Iowa Child Welfare Research Station, also at the State University of Iowa, who have made a careful study of the calcium needs of pre-school children under such dietary conditions as are prescribed today by the best nursery school nutritionists. They have answered the question as

[1] Sherman, H. C., and Hawley, E. "Calcium and Phosphorus Metabolism in Childhood." *Journal of Biological Chemistry*, Vol. 53, page 375 (1922).

[2] Stearns, G., and Jeans, P. C. "Utilization of Calcium Salts by Children." *Proceedings of the Society for Experimental Biology and Medicine*, Vol. 32, page 428 (1934).

[3] Daniels, A. L., Hulton, M. K., Knott, E. M., Wright, O. E., and Forman, M. "Calcium and Phosphorus Needs of Preschool Children." *Journal of Nutrition*, Vol. 10, page 373 (1935).

Fig. 46.—Foods Yielding about 0.023 Gram of Calcium.

	Grams		Grams
Asparagus	110	Beans, string	45
Celery	30	Carrot	64
Beet greens	25	Cauliflower	19
Peas, fresh	100	Clams	22
Milk, whole	19	Cheese	2
Cabbage	51		

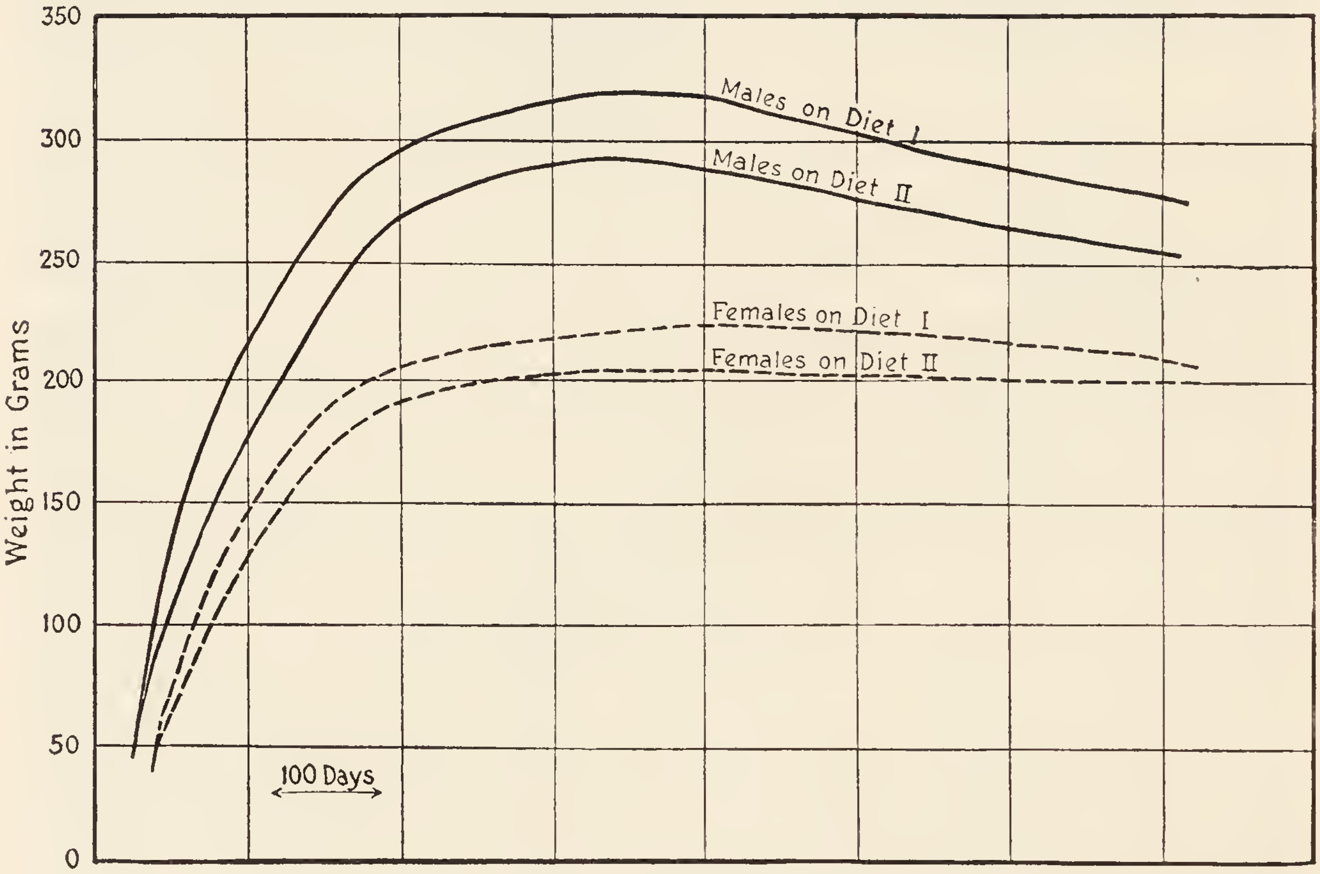
to whether the children studied in 1922 had sufficient vitamin D for the best calcium storage. Each child in their group of two girls and eight boys three to five years of age received twice daily a ten-minute exposure to the rays of a sun lamp and once daily a teaspoonful of cod liver oil with additional viosterol. This not only assured ample vitamin D but likewise vitamin A, which also favors calcium storage. Orange juice twice daily provided an excellent supply of vitamin C, which aids in the retention of calcium. The choice of foods was such that the children receiving a pint of milk daily were getting as much total calcium as those in the Sherman and Hawley study who received a pint and a half (750 cc.) of milk, the total daily intake of the Daniels group being 0.77 to 0.90 gram of calcium, and of the Sherman and Hawley group 0.74 to 0.92 gram for the same ages. This was sufficient to give daily retentions of the same magnitude as in the Sherman and Hawley study, mostly between 9 and 12 milligrams per kilogram. In both studies the difference in storage between intakes of about one gram per day and more did not make any marked increase in storage, as is shown in Fig. 45 by comparing periods III, IV, and V. Hence the dietary standard of one gram of calcium per day would seem very well established.

The question as to what a child can profitably use cannot be answered by any short-time experiment. We are concerned not only with well-being from day to day but also with effects on future health. In order to discover whether there are any real gains from some surplus of calcium over what appears to result in good storage, Sherman and Campbell [1] have observed the effect of two diets differing only in calcium content fed through several generations. The first diet consisted of five sixths ground whole wheat and one sixth dried whole milk with added common salt and distilled water to drink. On this diet rat families have prospered for as many as 40 generations, hence there is no doubt that

[1] Sherman, H. C., and Campbell, H. L. "Effects of Increasing the Calcium Content of a Diet in which Calcium Is One of the Limiting Factors." *Journal of Nutrition*, Vol. 10, page 363 (1935).

it is an adequate diet. The second diet differed from the first only in the addition of calcium carbonate to make the calcium intake equal to that in a quart of milk instead of a pint.

On the calcium-enriched diet, growth was somewhat more rapid and average size at a given age somewhat greater as shown by growth curves for each sex in Fig. 47. The appearance and behavior of the adult animals indicated that



(*Courtesy of Professor H. C. Sherman and Dr. H. L. Campbell*)

Fig. 47.—Records through life of rats on a diet enriched with calcium (Diet I) compared with those of rats on a diet adequate for growth through 40 generations but not so rich in calcium (Diet II).

the more liberal calcium intake resulted in a higher vitality and its maintenance over a longer time. The females matured somewhat earlier, showed a longer period of ability to bear young, and reared a higher percentage of them. The males, not having the strains of maternity, manifested their greater vigor by longer life and a longer period between the attainment of maturity and the onset of senility. Thus improved growth, greater adult vitality, lowered death rates, and increased length of life show that the increased calcium improved the nutritive value of a diet which by all ordinary signs would be adjudged adequate.

"In human nutrition" Sherman [1] points out, "the enrichment of the diet in calcium should normally be accomplished, not by the use of calcium salts as such, but rather by increasing the consumption of calcium-rich food, especially milk, which contains along with its abundant calcium content, such proportions also of phosphorus and other mineral elements as to insure improvement of the dietary in its mineral content as a whole."

The Requirement for Iron

Long before the importance of calcium and phosphorus in vital processes was fully realized, the connection between iron in the blood and the oxidative processes in the body had been discovered. Lavoisier made the mistake of thinking that oxidation took place in the lungs, but before his death a mathematician, Lagrange, considering that the temperature of the lungs was not higher than that of the rest of the body, expressed the conviction that oxygen "dissolved" in the blood and that heat might be generated wherever the blood carried the oxygen. It was not until 1838, however, that the Swedish chemist, Berzelius, showed that the red coloring matter of blood was capable of absorbing much oxygen and concluded that this was due to the iron in this pigment. We now know that we have in the human body about 25 million times a million red blood corpuscles, owing their color to the iron-bearing protein, hemoglobin, and through its agency transporting oxygen through all the intricacies of arteries and capillaries to the innermost cells of every organ and tissue.

Not only in the red blood corpuscles, but very generally in active cells, both animal and vegetable, we find iron as an essential part of the cell structure and functioning as a stimulator of the vital processes of the cell. Therefore, as a carrier of oxygen and as an activator of cell functions, iron has significance out of all proportion to the amount in the

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 5th edition, page 289. The Macmillan Co. (1937).

body—less than one tenth of an ounce, or the weight of a cent.

Notwithstanding its great prominence in vital activities, there is little reserve store of iron in the body and the amount present in different food sources is also relatively small. Hence we live a kind of hand-to-mouth existence so far as this element is concerned and it becomes important indeed that there be an adequate daily supply and favorable conditions for its utilization.

The iron in food, absorbed from the small intestine, is deposited mainly in the liver, bone marrow, and spleen where it is built into the complex iron-bearing proteins of the body (chiefly hemoglobin). When old worn-out red blood corpuscles are finally disintegrated, the iron is returned to the intestinal canal for elimination. Very little is excreted in the urine. Studies of iron requirement are difficult to make. Periods of observation need to be long and the analytical technics require skill and the most meticulous care. Consequently the number of cases furnishing accurate knowledge of minimal requirement is still very small compared to the satisfactory cases used in determining calcium and phosphorus requirements. Recently an unusually long study of iron requirement of adult men was conducted by Dr. G. E. Farrar and Dr. S. M. Goldhamer [1] at the Thomas Henry Simpson Memorial Institute for Medical Research of the University of Michigan. One man lived for 316 days on a practically uniform diet, consisting of milk, cream, bread, butter, jelly, shredded wheat, canned grapefruit, and distilled water, and during the last month of this régime an iron balance was maintained on 5.2 milligrams of iron daily.

This is in close agreement with a study by Sherman of a man on a diet composed of bread and milk exclusively. Here as in the earlier work of von Wendt and the later work of Orten, Smith, and Mendel there is indication that a liberal calcium content of the diet conduces to efficient use of iron,

[1] Farrar, G. E., and Goldhamer, S. M. "The Iron Requirement of the Normal Human Adult." *Journal of Nutrition*, Vol. 10, page 241 (1935).

and this would seem to apply almost equally well in the case of Farrar and Goldhamer. Other studies show iron requirements ranging upward from 5.2 milligrams to at least 11 or 12. From consideration of the available data Sherman [1] concludes that the average requirement is about 8 milligrams per day.

As in the case of calcium and phosphorus, it is important that there should be a good margin of safety in a dietary standard for iron.

One reason for a generous surplus of iron is that many minor disturbances in the body cause loss of iron and there are no large reserves to draw upon as in case of calcium and phosphorus. Infections, however mild, are a common cause of iron loss, and the individual taking just enough to maintain equilibrium may, as Dr. George R. Minot,[2] one of the recipients of the Nobel prize for his work on pernicious anemia says, "be precipitated into the zone of partial deficiency by the advent of infection."

Just how much surplus is desirable to provide for these contingencies it is difficult to say. But between 12 and 15 milligrams per day would seem to be safe. Since a diet which is meeting liberal standards for other essentials will easily furnish 15 milligrams of iron, and since considerable amounts of iron in available form can very cheaply be obtained from cereals and milk, 15 milligrams per 3,000 calories has been made the basis of recommendations for adult men in this book. When the energy intake is not more than 2,500 calories, as for many men not doing manual labor, the iron allowance will then be about 12 milligrams per day.

Studies of the iron metabolism of women made in the intermenstrual period indicate that the losses of menstruation are the main factor in differences between the iron requirements of men and women. But menstruation is a cause of considerable iron loss, the average per period for 100 women

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 5th edition, page 317. The Macmillan Co. (1937).

[2] Minot, G. R. "The Anemias of Nutritional Deficiency." *Journal of the American Medical Association*, Vol. 105, page 1177 (1935).

being 19.5 milligrams. In an investigation of the iron metabolism of four young college women, in two cases through 110 days and in the other two through 140 days, Leverton and Roberts [1] found average losses of 11, 13, 14, and 22 milligrams respectively. This is one of the few studies of sufficient duration and sufficiently well controlled to throw light on the iron requirements of women. The dietary approximated more closely the usual variety of foods than in most metabolism studies. A basal diet was planned for a five-day period, the way the foods were combined within the period being left to the choice of the subjects. This allowed about a pint of milk per day, 2.3 ounces of lean beef, two ounces of whole wheat bread, and a generous supply of fruits and vegetables, including potatoes both white and sweet, and about two eggs for the period.

On iron intakes which amounted to from 10 to 12 milligrams per day for a woman of average weight (56 kilograms) three of the four subjects just about maintained equilibrium or showed a slight positive balance. The fourth, on the lowest intake per kilogram had a higher positive balance than any of the others.

Considering the character of the diet, no additional allowance for availability of iron would seem to be necessary, but as a safeguard against other contingencies which have been already indicated, a standard of at least 15 milligrams per day for the average woman would seem highly desirable. One of the ways in which women generally can improve their health and vigor is by maintaining a higher level of hemoglobin than they commonly do. A standard should provide enough margin to allow them to attain a hemoglobin of approximately 14 grams per 100 cubic centimeters of blood.

A diet which covers the losses of menstruation will go far towards meeting the needs of pregnancy because what was formerly lost will be available for the fetus. However,

[1] Leverton, R. M., and Roberts, L. J. "The Iron Metabolism of Normal Young Women during Consecutive Menstrual Cycles." *Journal of Nutrition*, Vol. 13, page 65 (1937).

there must be iron not only for its normal development, but to enable it to accumulate a reserve for use during the first few months of lactation. And also there is frequently in pregnancy a decreased secretion of acid in the stomach which interferes with iron absorption. It has been noted often in the last few years that many women in the later weeks of pregnancy have a low blood hemoglobin. To what extent diet can overcome this is not known as yet, for the necessary studies have not been made. But some light on the capacity of the mother to store iron is shown from a study by Dr. Callie M. Coons,[1] at the Oklahoma Agricultural Experiment Station. For 101 days the same diet was eaten, and for 82 days the food was weighed and collections of excreta made. The diet furnished from 18 to 20 milligrams of iron per day, and storage amounted to from 2 to 6 milligrams. When wheat germ or wheat germ ash was added to raise the iron intake to 24 to 28 milligrams, the storage increased, approximating 7 to 9 milligrams as a rule, but in two different periods it rose to about 11 milligrams. This study seems to indicate that 20 milligrams or more per day can be profitably used by pregnant women in the latter half of pregnancy when fetal growth and fetal storage are approaching their maximum. A safe iron allowance for pregnancy and also for lactation, would seem to be not less than 15 milligrams per day and preferably somewhat more.

The Iron Requirement of Children

The baby comes into the world bearing in its body a special store of iron which serves as a reserve during the period of lactation. The percentage in the infant's body at birth is about three times that in the adult's. This store has been regarded as sufficient to compensate for the low iron content of mothers' milk through the first half year of life, but many recent studies have shown that especially

[1] Coons, C. M. "Some Effects of Cod Liver Oil and Wheat Germ on the Retention of Iron, Nitrogen, Phosphorus, Calcium and Magnesium during Human Pregnancy." *Journal of Nutrition*, Vol. 10, page 289 (1935).

with the artificially fed baby recovery after the drop which is normal in the second month is more rapid and a higher level of hemoglobin is attained and maintained if some special source of iron, such as egg yolk, a special cereal reinforced with iron or a simple iron salt is introduced into the diet as early as the third or fourth month. A slight anemia in infants and young children, formerly regarded as unimportant, has been shown to retard growth and make the infant more susceptible to infection. When this is coupled with the fact that infection causes a considerable loss of iron, it is easy to see how a liberal intake of iron becomes a real safeguard of health. A notable study of the influence of anemia on infants was made by Dr. Helen Mackay [1] in London. During a five-year period over 1,000 babies were under her observation, brought by poor mothers to the clinics of the Queen's Hospital for Children. Dr. Mackay found that at five months of age only 10 per cent of the artificially fed and 16 per cent of the breast fed reached a hemoglobin level of 11 grams per 100 cc., which she considered normal, although according to Dr. C. A. Elvehjem of the Wisconsin Agricultural Experiment Station and Dr. Dorothy Reed Mendenhall,[2] an expert pediatrician, the normal content of the blood of infants between the ages of three months and one year should be between 12 and 13.5 grams. In the older babies when first examined Dr. Mackay did not find the situation much better, as of those 12 and 13 months old 70 per cent of the artificially fed and 42 per cent of the breast fed were still below the level of 11 grams per 100 cc. None of these infants were suffering from any specific disease, but nevertheless the improvement with iron treatment was very great. When the artificially fed infants were given daily small amounts of ferric ammonium citrate, an inexpensive and readily available source of iron, the

[1] Mackay, H. M. M. *Nutritional Anemia in Infancy with Special Reference to Iron Deficiency.* Medical Research Council of Great Britain, Special Report Series No. 157 (1931).

[2] Elvehjem, C. A., Siemers, A., and Mendenhall, D. R. "Effects of Iron and Copper Therapy on the Hemoglobin Content of the Blood of Infants." *American Journal of Diseases of Children,* Vol. 50, page 28 (1935).

majority of them showed a rise in hemoglobin and in 69 per cent it was maintained at the 11 gram level. The infants between three and six months of age who had three months or more of iron feeding averaged about two pounds heavier than their mates in the control group, of the same average weight at the beginning, an advantage maintained through the remainder of their six months' feeding period.

An investigation to discover the best conditions for iron storage in infants has been conducted by Stearns and Singer [1] who find that at least 0.5 milligram per kilogram is necessary to secure any retention, but that it is more regular as well as considerably greater when from 1.0 to 1.5 milligrams per kilogram are given, whether the source of iron be eggs, an iron-enriched cereal, or a simple iron salt. In terms of total calories this would indicate that 0.75 milligram per 100 calories should be a conservative but safe allowance for the ordinary healthy child during the first two years.

Up to 1930 there had been no effort to determine the iron requirements of the nursery school child. In that year Rose, Vahlteich, Robb, and Bloomfield made a beginning at Teachers College with a study of a two- and one-half-year-old girl. In 1934 Daniels and Wright [2] at the Iowa Child Welfare Research Station made 15 balance experiments on 8 children three to six years old and the next year Dr. Leah Ascham [3] at the Georgia Agricultural Experiment Station reported a study on six children four to six years old. In these 15 children, there was equilibrium but little or no storage when the iron intake lay between 0.40 and 0.55 milligram per kilogram. Significant storage occurred on 0.60 milligram per kilogram, but retention was considerably higher when the diet furnished 0.65 to 0.75 milligram per kilogram. Taking 80 to 90 calories per kilogram as representative of the energy needs of the pre-school child, these studies indi-

[1] Stearns, G., and Singer, D. "Iron Retention in Infancy." *Journal of Nutrition*, Vol. 13, page 127 (1937).

[2] Daniels, A. L., and Wright, O. E. "Iron and Copper Retentions in Young Children." *Journal of Nutrition*, Vol. 8, page 125 (1934).

[3] Ascham, L. "A Study of Iron Metabolism with Preschool Children." *Journal of Nutrition*, Vol. 10, page 337 (1935).

cate that an allowance of 0.6 to 0.7 milligram per 100 calories is desirable for children three to six years old. This is borne out by the studies of Rose and Borgeson [1] on a group of 60 nursery school children under observation continually from 6 to 21 months, on a simple, inexpensive diet in which two thirds of the total calories came from milk and cereals, and one fifth from fruits and vegetables. One half of the children had an egg added to their diet daily, with the result that the iron intakes of the group receiving eggs ranged from 0.5 to 1.0 milligram per kilogram of body weight, while in the other group they lay between 0.4 and 0.7 milligram per kilogram. Hemoglobin tests were made at four-month intervals, and out of 131 tests on children in the egg group, 40 per cent showed values of 12.5 grams per 100 cc. of blood or more, while out of 114 tests on children in the no-egg group, only 22 per cent reached or exceeded this level. Thus while the difference in the iron intakes was small, the children having the eggs made a distinctly better record, and from a careful dietary study it was indicated that while all but three of the children in the egg group received from 0.5 to 0.7 milligram per 100 calories, more than one third of the children in the no-egg group fell below 0.6 milligram per 100 calories. For iron as for calcium there is a distinct advantage for the growing child in an intake which will allow a considerable surplus above daily requirement, and since the chances of iron loss appear to be greater than of calcium loss, the supply of iron should be even more liberal. The above study shows that an intake of 0.7 milligram per 100 calories is attainable on diets of minimum cost.

Most of our knowledge of iron requirements of older children comes from dietary studies of normal, well nourished subjects. Koehne and Morell in their studies of girls six to 13 years old estimated the iron in the weighed food over a long time as from 0.37 to 0.53 milligram per kilogram or

[1] Rose, M. S., and Borgeson, G. M. *Child Nutrition on a Low-Priced Diet.* Child Development Monographs No. 17, Bureau of Publications, Teachers College, Columbia University (1935).

from 0.6 to 0.7 milligram per 100 calories and hemoglobin tests showed that the girls were not anemic. Wait and Roberts found the intake for girls 10 to 16 years of age to range from 0.35 milligram per kilogram at 10 years to 0.18 at 16 years, and for all these ages to be about 0.5 milligram per 100 calories. Since boys tend to have a much higher energy intake, an allowance of 0.5 milligram per 100 calories would seem satisfactory for ages above six years.

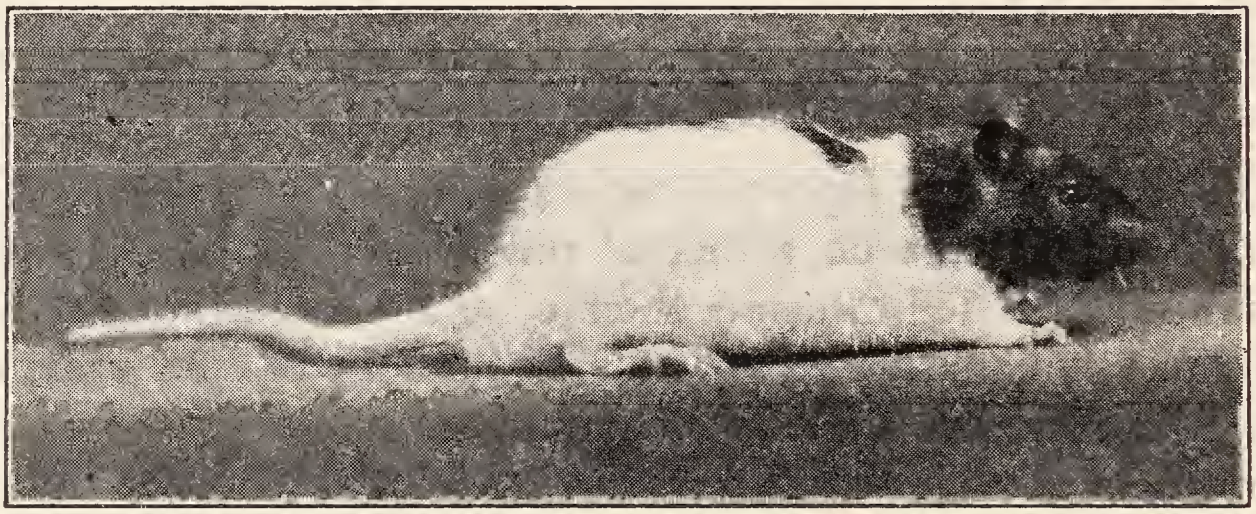
Milk and Nutritional Anemia

In 1889 Bunge reported the case of a young man who developed anemia on a diet of milk only. He also found that mice so fed became anemic, and that although the obvious explanation was the small amount of iron present in milk, the cure was not so simple, inasmuch as the addition of a pure iron salt had but little effect. Since much better results were obtained with egg yolk, Bunge concluded that the difference was due to the peculiar chemical union of the iron with protein in the egg yolk. A few years later Abderhalden, in a critical review of the work of Bunge and others, summarized the knowledge of that period as follows: "The mere fact that the addition of iron to nutriment poor in iron does not have any distinct influence upon the formation of hemoglobin, in no way speaks against the participation of inorganic iron in the synthesis of hemoglobin in the case of normal nutrition, but it indicates that other building material is wanting as well as iron." [1]

Here the matter rested for a long time. In 1925 Hart and Steenbock found, like Bunge and Abderhalden, that when rabbits had been made anemic by feeding milk as the sole source of iron, the addition of inorganic iron did not cure them. When cabbage was fed as a supplement to the milk, the anemia developed slowly, but if some pure iron salt were added to the milk and cabbage diet no anemia whatever appeared. The ash of dried lettuce was also found

[1] Abderhalden, Emil. *Textbook of Physiological Chemistry*, translated by Hall, page 398. John Wiley and Sons (1908).

remarkably effective. Other investigations made it evident that something in addition to iron must be added to milk to make hemoglobin. In 1926 Hart and his associates decided to try the white rat for studies of iron metabolism although it had been reported that otherwise well balanced diets, deficient in iron, would not produce anemia in rats in the first generation—only in the second or third. On



(*Courtesy of Drs. E. B. Hart and H. Steenbock*)

FIG. 48.—The First Rat Made Anemic on a Diet of Whole Milk and Cured by Adding Iron and Copper to the Milk.

fresh cow's milk secured directly from a group of cows on a carefully controlled diet, the rats grew well for a period of 4 to 6 weeks, then they stopped growing and became very pale. This was especially noticeable in the eyes which are normally a deep rose pink. When the animals had been on the milk diet six weeks, fatalities began to occur, which multiplied as time went on. Here again, as in case of rabbits, lettuce ash was an effective cure, while pure iron salts were not. The ash of beef liver or of corn was also a cure, but the ash of beef muscle had practically no effect. What unknown substance was common to the ash of lettuce, corn, and beef liver?

Observation (1928) of a blue color in the lettuce and liver ash finally suggested the possibility of copper being the potent factor and an anemic rat was given 0.5 mg. of iron as a pure iron salt (ferric chloride) plus 0.25 mg. of copper as a pure copper salt (copper sulfate) as a supplement to an exclusive milk diet. The authors describe the result thus:

"The response in this preliminary experiment of copper sulfate feeding was indeed surprising. This preliminary experiment was with but a single animal but the effect was so convincing and helpful that we want to record in Chart V the weight record and hemoglobin curve of this single animal if for no other reason than its historical interest. We think that this is the first experiment in the literature giving to copper in association with iron the specific function of hemoglobin building in a mammal on an otherwise satisfactory diet." [1]

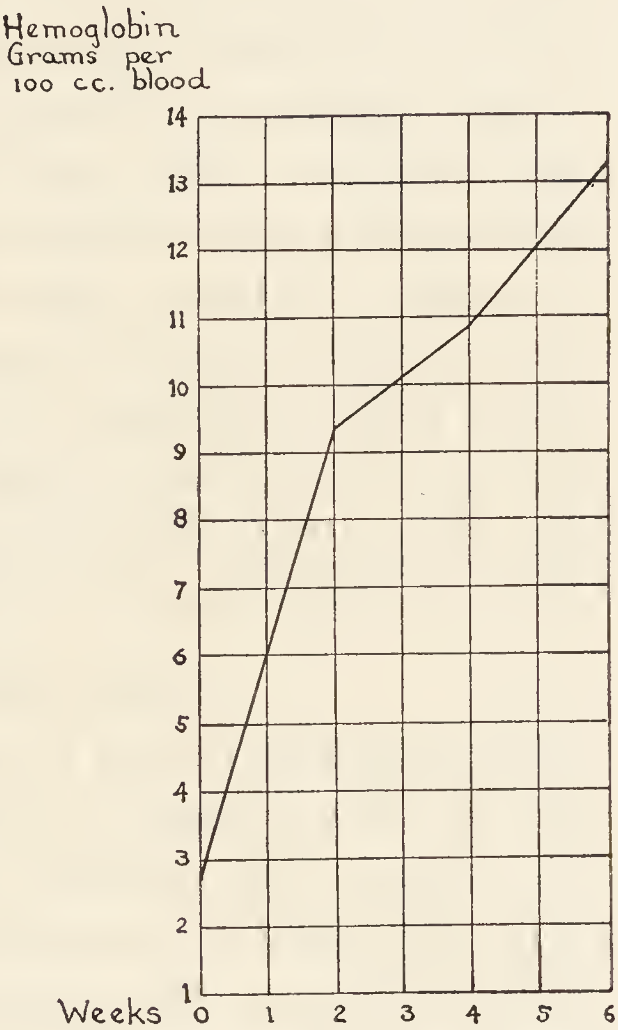


FIG. 49.—Changes in the hemoglobin of the rat shown in Fig. 48, during six weeks, following the administration of iron and copper. On the milk alone, hemoglobin fell to 2.68 grams per 100 cc. of blood; after the addition of one half milligram of iron and one fourth milligram of copper per day it rose in six weeks to 13.3 grams per 100 cc.

The inadequacy of milk for hemoglobin building was now explained. It was relatively poor in both iron and copper. The young child comes into the world with an extra supply of iron for the lactation period; has it a similar reserve of copper? Since 1928 many investigators have shown that the liver of the newborn of many species including man is strikingly high in copper. Cunningham reports the liver of a human fetus as containing 10 times as much copper per kilogram of dry substance as that of an adult.

Such laboratory findings enable us to understand the anemia sometimes observed when infants have been fed nothing but milk (often much diluted with water and reinforced as to calories with sugar) for long periods, and the

[1] Hart, E. B., Steenbock, H., Waddell, J., and Elvehjem, C. A. "Iron in Nutrition. VII. Copper as a Supplement to Iron for Hemoglobin Building in the Rat." *Journal of Biological Chemistry*, Vol. 77, page 806 (1928).

improvement when egg yolk and green vegetables are given with the milk. In nutritional anemia, it is now quite evident that the course to pursue is not to take away any of the milk, as its iron is very efficiently used, but to reinforce it with those foods known to yield both iron and copper.

Since copper is constantly added to food more or less accidentally, as when milk is pasteurized by being passed over heated copper rollers, or when copper cooking utensils are used, and since most cereals, fruits, vegetables, and meats contain appreciable amounts, it does not seem necessary to estimate copper in the ordinary mixed diet. Therefore no table of copper content of foods is included in this book but one may be found in Sherman's *Chemistry of Food and Nutrition*, 5th edition, 1937.

Other Foods and Anemia

The ability of a child to secure enough iron for the maintenance of an optimum level of hemoglobin while growing at a normal rate depends upon many factors. Iron and copper are essential but animals deprived of vitamins become anemic when iron and copper are both provided. On a diet consisting of one third dried whole milk and two thirds whole wheat, Sherman found that young rats had a better store of iron than when the milk was reduced and more wheat included although this change resulted in a higher iron intake; due probably to the better supply of calcium.

A large number of experiments have been undertaken in an effort to learn about the hemoglobin-producing values of food in rats made anemic by milk feeding. When a food is as good a source of iron as a pure iron salt, which induces a rapid and complete regeneration when fed in suitable quantity, this would seem good evidence that its iron can be readily absorbed from the alimentary tract. The results with wheat and oats have been such as to justify the view that the iron of cereals can be efficiently used. Since these foods are very inexpensive sources of iron, the cost per 100 calories of the whole grain products exceeding little, if at all,

that of highly milled ones, even the cheapest diet need not be inadequate in iron, especially if milk is also liberally provided.

Eggs have not served so well as a supplement to milk for the rat, owing to an insufficiency of copper caused by formation in the intestines of copper salts incapable of absorption but as copper is abundant in mixed diets it seems hardly likely that shortage of copper will interfere appreciably under ordinary circumstances with the utilization of egg iron. A comparison of the availability of the iron of egg and of wheat (using the bran, which is the main source of iron in wheat) in a balance experiment on two women, when the amount of iron in the diet was barely sufficient to meet daily requirement, so that any failure to utilize either would result in a negative balance, showed equally good utilization of both.[1] The long study of Rose and Borgeson, already referred to, also affords evidence of the efficiency of the iron of the egg yolk for hemoglobin regeneration. Thirty children whose iron intake was increased on the average about 10 per cent by the daily addition of an egg to their diet manifested a definite trend toward higher hemoglobin values than an equal number carefully paired with them as to age, sex, and living conditions, who received no eggs. The results of hemoglobin determinations made at intervals of four months are shown in Fig. 50.

The amount of inorganic iron present in foods is now being extensively investigated by means of a colorimetric test, but colorimetric tests for inorganic iron in foods, while of great interest, cannot be used as criteria of the way the iron of a given food is going to be used by a human subject unless they have been substantiated by balance experiments and blood tests on human beings. So able an investigator of iron metabolism as Bunge found no inorganic iron in the egg yolk but isolated considerable amounts of a phosphorized pro-

[1] Vahlteich, E. McC., Funnell, E. H., MacLeod, G., and Rose, M. S. "Egg Yolk and Bran as Sources of Iron in the Human Dietary." *Journal of the American Dietetic Association*, Vol. 11, page 331 (1935).

tein containing about 0.3 per cent of iron in such firm combination with the protein that it gave none of the ordinary reactions of iron salts. Another expert investigator, Dr. A. B. Macallum of the University of Toronto, followed the absorption of iron in various forms by microscopic examination of the intestinal wall and the various organs and tissues of the

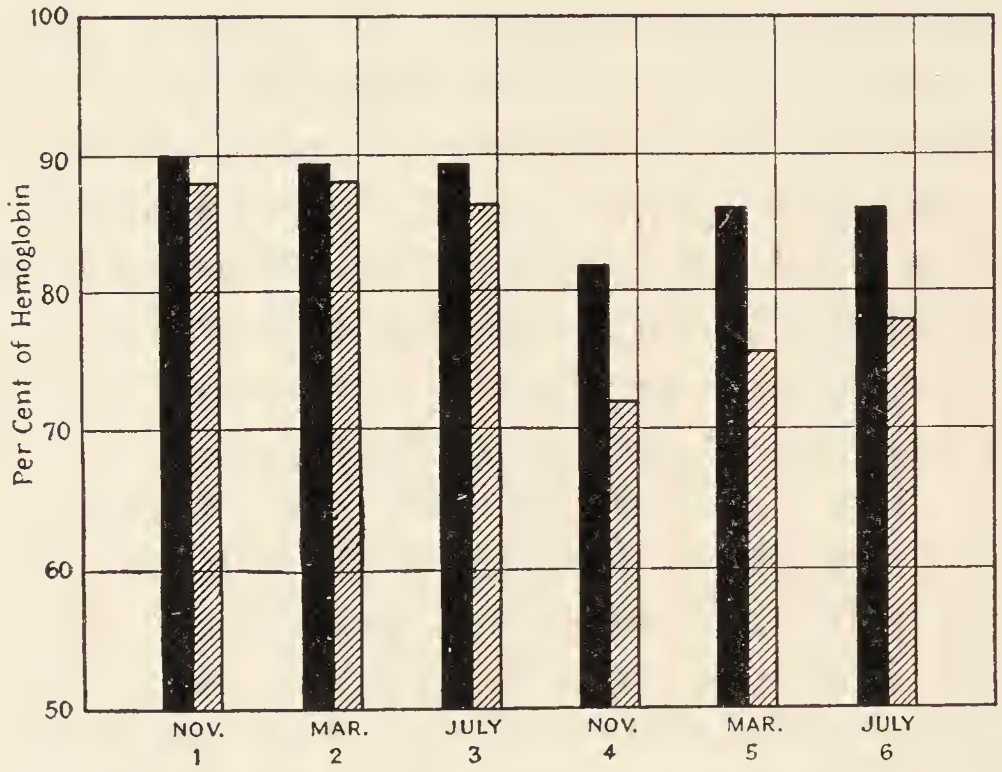


Fig. 50.—Median hemoglobin values for a group of children whose iron intake was increased about 10 per cent by addition to the diet of an egg a day (solid black column) compared with a group carefully matched with them, who received no iron addition (cross-hatched column), showing a more marked effect in the second year than the first.

body and found that iron taken either in the form of the iron compound of egg yolk or as inorganic salts was well absorbed by the small intestine.

The anemic rat on an exclusive milk diet uses inorganic iron more efficiently for hemoglobin formation than the iron of liver or lean beef. Many years ago Sherman called attention to the fact that the iron of meat is largely due to the blood retained in the tissue and from a careful survey of the evidence concluded that "so far as the iron compounds of blood are concerned, it seems to be established that hemoglobin and hematin may be absorbed and assimilated to some extent, but probably not to as good ad-

Fig. 51.—Foods Yielding about 0.0005 Gram of Iron.

	Grams		Grams		Grams		Grams
Lettuce	100	Tomato	125	Egg	17	Prunes	17
Bread, whole wheat	31	Cabbage	125	Oats, rolled	10	Raisins	17
Onions	111	Beans, navy, dried	5	Beef, lean	17	Peas, fresh	24
Spinach	19						

vantage as the iron compounds of eggs, milk and vegetable foods."[1]

Further balance studies need to be made of the effects of mixtures of foods on human subjects. Vegetables as well as cereals furnish copper along with iron, and add at the same time to the vitamin content of the diet. The increasing use of canned fruits and vegetables results in the intake of considerable iron from the can. Thus puréed prunes canned in glass were found to have an iron content of 0.0011 per cent, while a similar product canned in tin for only a few weeks, had an iron content of from 0.0042 to 0.0062 per cent. A table giving the approximate iron content of many foods will be found in the Appendix.

The experimental anemia induced by exclusive milk feeding, while useful in studying iron metabolism, is not the type commonly found in daily life. There would seem to be other causes for most anemias than simple lack of iron or copper. Any anemia due to faulty nutrition will be helped by bringing the diet to optimum in every respect, but can only be fully coped with by careful study of many possible factors.

For the most part anemia may be regarded as a medical, more than a dietary problem, once we are sure that an adequate diet has been fed. Thus pernicious anemia is a disease in which there is a deficient formation of mature red blood corpuscles, and no amount of iron will cure it. On the other hand, feeding with liver or kidney in large amounts results in immediate increase in the number of young red cells and the number of mature corpuscles is rapidly restored to normal. This is not due to iron and copper but to some still unidentified organic substance, which can be extracted from the liver and is now obtainable commercially. This substance is also produced when beef is digested, outside the body, by normal gastric juice. A normal person is able to make this substance, essential to red cell formation, by digestion of protein food in the stomach; a patient with pernicious

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 1st edition, page 253. The Macmillan Co. (1911).

anemia unfortunately cannot do this and must have it constantly furnished to him ready made just as the diabetic must have insulin as a medicine when his pancreas fails to supply it.

Anemia may occur through accidental loss of blood. This anemia of hemorrhage is cured only by the complete reconstruction of the lost blood. In this process liver has been found to be especially effective, and meat in general better than spinach or other vegetables. Whipple and Robscheit-Robbins in testing various foods for their effectiveness in the cure of anemia induced by bleeding, have found the following especially valuable: chicken liver and gizzard, beef liver and kidney, eggs, apricots, and raisins. All of these were superior to spinach, asparagus, and muscle meats but the cause of these differences is still unknown.

For the normal person, the best guarantee against anemia so far as food is concerned, is a diet rich in mineral elements and vitamins, in addition to suitable calories and protein. If anemia then persists, a physician should determine the cause and the remedy.

The Requirement for Iodine

Our knowledge of quantitative requirements for mineral elements other than phosphorus, calcium, and iron is still meager, but since the foods which supply these three contain a variety of other mineral elements, it does not appear to be likely that a diet adequate in them will be inadequate in others, save in those regions where endemic goiter gives evidence of a low supply of iodine.

This element has already been referred to as essential to the thyroid gland, which serves as an important regulator of the basal energy metabolism and an indispensable factor in normal growth. Yet it was not until 1895 that conclusive evidence was brought forth that iodine was an essential element in thyroid structure and not until 1914 that thyroxin was prepared from the gland by Dr. E. C. Kendall of the Mayo Clinic at Rochester, Minnesota, and shown to be an iodine-containing substance of marked physiological properties.

When Kendall was able to remove iodine from thyroxin and show that the resulting product would not stimulate development, the place of iodine among nutritionally essential mineral elements could no longer be questioned, minute as the total amount in the body is—only about one hundredth as much as of iron or less than the weight of one grain of wheat.

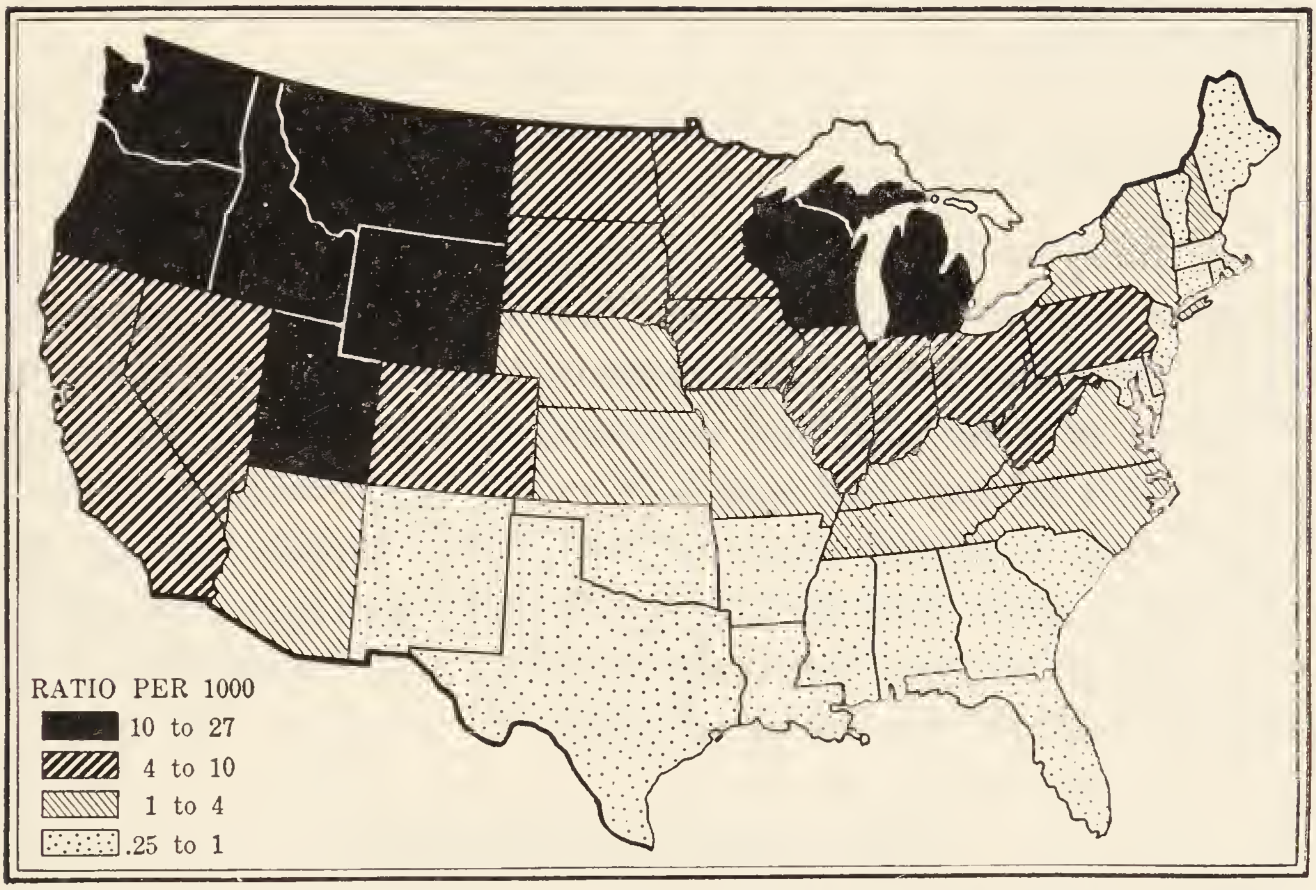
Various species of animals have been found to suffer from iodine deficiency; it was estimated in 1916 that about one million young pigs were lost annually in Wisconsin because of being born hairless and otherwise defective. In other western states (North and South Dakota, Washington, Minnesota) the pig industry was similarly menaced. The mothers appeared normal, but the thyroid glands of hairless offspring were found to be abnormally large and abnormally low in iodine. A careful canvass of the whole situation brought the conclusion that iodine starvation of the fetus depressed the activity of the fetal thyroid and caused the remarkable arrest of development. When suitable amounts of iodine were administered to the mothers during the gestation period there was not only prevention of the hairless condition but also a marked improvement in the vitality of the young pigs.

Other farm animals, such as horses, cattle, chickens, and dogs, have suffered extensively from goiter, and in all of these species administration of iodine has been as successful as with pigs.

As old as history itself is the incidence of goiter in the human race. Kimball remarks that the *Arthorva Veda*, an ancient Hindu collection of incantations dating from 2000 B. C., contains extensive forms of exorcisms for goiter. It was not until the middle of the nineteenth century, however, that the prevalence of goiter in European countries was made a matter of government investigation. For France alone, a commission appointed in 1864 reported ten years later 500,000 people suffering from goiter, and 120,000 cretins and cretinoid idiots. In all southern Europe the problem of

goiter and cretinism has been of sufficient economic importance to justify national commissions for its investigation.

In the United States there is a wide goiter belt stretching along the Appalachian Mountains as far north as Vermont, westward through the basin of the Great Lakes to the state of Washington, and southward over the Rocky Mountain and Pacific states; but no attempt to prevent human goiter on a large scale seems to have been made previous to 1917.



(*Courtesy of the United States Public Health Service*)

FIG. 52.—Map showing ratio of simple goiter per 1,000 men examined for military service in each State of the United States during the World War. The rates are based on a total of 2,510,701 examinations.

Then Marine and Kimball, reasoning that if goiter could easily be prevented in brook trout, cattle, sheep, pigs, and poultry by administration of minute amounts of iodine, it should be preventable also in the human species, undertook to prove the possibility of such prevention in the public schools of Akron, Ohio, a large manufacturing town in the goiter belt. They secured the coöperation of the Superintendent of Schools, the Board of Education, and the County Medical Society, and in April, 1917, began a systematic census of the thyroid glands of all the girls from the fifth to the twelfth

grades of the elementary school. The boys were not examined because of the relative infrequency of serious thyroid enlargement in boys. The results were as follows:

Incidence of Goiter in School Girls of Akron, Ohio, in 1917

State of Thyroid Gland	Number of Girls	Per Cent of Total Number Examined
Normal	1,688	43.6
Slightly enlarged	1,931	49.9
Moderately enlarged	246	6.3
Markedly enlarged	7	0.2
Toxic	39	1.0
Total number examined	3,872	

As many of these girls as volunteered were given small doses of sodium iodide dissolved in drinking water in quantity to furnish from 3 to 5 milligrams of iodine twice weekly over a period of a month, and repeated twice yearly. In 1920, as a result of two and one half years' observations, the investigators reported that of over 2,000 pupils taking the treatment only five developed thyroid enlargement, while of a similar number not treated nearly five hundred showed enlargement during the same time.

Iodine and Goiter Prevention

This strikingly successful demonstration aroused much interest in goiter prevention both in other parts of this country and abroad. In the spring of 1918, Professor R. Klinger of Zurich, Switzerland, undertook to carry out similar treatment in three Swiss cantons, Saint Gallen, Berne, and Zurich, with school populations in which the incidence of goiter varied from 82 to 95 per cent. In 1922 a report of the Health Commission of the Canton of Saint Gallen gave the following statistics: incidence of goiter among all the school children of Saint Gallen, January, 1919, 87.6 per cent; January, 1922, 13.1 per cent. By 1929 there were nine cantons in which only iodized salt was used and in all but a few of the others it was consumed more or less freely, so

that between 1922 and 1929 the total consumption of the country had increased from 200,000 kilograms to 14,482,000. In the Canton of Appenzell the Swiss Goiter Commission reported that after five years there was a total disappearance of congenital goiter and of goiter among young school children, with a fall of 75 per cent in operations for relief of goiter in adults. There was also a decline in the number of stillbirths and infant deaths due to thyroid deficiency and an average increase of 100 grams in the birth weight.

In this country Michigan has been one of the foremost states in establishing and maintaining a goiter prevention program. In 1928, after four years of educational work on the part of the State Medical Society and the State Board of Health, and continued effort on the part of the Wholesale Grocers' Association to bring about the sale of iodized salt exclusively, the school children were examined in certain districts to see what the effect of the policy had been. In every instance the decline in the incidence of goiter was striking. A part of the plan was a general resurvey in ten years and this was made in 1935, with the result that the percentage of goiter was reduced from 40 in 1924 to eight in 1935. In Midland County, where the original survey had shown fully one third of the children to have well established goiters and practically every child to have some enlargement, the disease has been almost completely stamped out, 90 per cent of the children being reported as normal. An interesting incident of the survey was the situation in the town of Calumet, where closing of the copper mines in 1932 had thrown two thirds of the families upon relief. These families were given only plain bag salt. Furthermore, families who were buying their own groceries were many of them in such financial straits that they, too, bought bag salt because it was cheaper. Thus the use of iodized salt was discontinued through the next three years, with the result that the number of cases with goiter, which had been reduced to a very low figure, became as great as before 1924.[1]

[1] For further reports, see Oleson, R. *Endemic Goiter*, Public Health Bulletin No. 192,

The prevention of goiter has thus been shown to be a nutritional problem. The body has a more or less definite requirement for iodine, to meet daily losses and maintain such a reserve as is necessary for the production of sufficient amounts of thyroxin for health and growth. A man requires perhaps five milligrams of iodine per year, a quantity which would make a three years' supply of iodine equivalent to the amount of iron needed for a single day. The most commonly used salts now contain an added quantity of from five to 10 milligrams of potassium iodide per kilogram of salt. Marine recommends the higher amount because it will take care of a wider range of iodine deficiencies, especially those of pregnancy.

"The added iodide is not to be regarded as a drug but rather as restoring the table salt to something like its natural composition—the ordinary table salt of today being the product of a highly artificial refining process and being thus in a sense denatured. Thus in the case of Charleston, W. Va., cited by McCollum and Simmonds, the community up to 1898–1900 had used relatively natural salt from local salt wells and had been practically free from goiter; but between 1898 and 1900 this was almost entirely displaced by the now familiar refined table salt and thereafter a larger proportion of the school girls began to show enlarged thyroids." [1]

Iodine in Food and Water

Our knowledge of the iodine content of food materials is as yet very limited, owing largely to the technical difficulties involved in determining such minute amounts of iodine as are found in common articles of diet. A curious instance of a single item of the diet preventing goiter is found in Pemberton Valley in British Columbia. It is said that in former years every white baby born in this valley had a goiter, and nine tenths of all the colts and the calves died.

U. S. Public Health Service (1929); and Kimball, O. P. "Prevention of Goiter in Michigan and Ohio." *Journal of the American Medical Association*, Vol. 108, page 860 (1937).

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 5th edition, page 343. The Macmillan Co. (1937).

Yet in a village of Indians in this valley there was never any goiter, although Indians living in Minnesota, Michigan, and Wisconsin are as frequent victims as the white inhabitants. Keith, who has studied the Pemberton Valley, comments thus on the situation: "Whilst considering the lack of goiter among these Indians I would like to draw attention to the fact that they eat a great deal of salmon . . . and annually cure thousands for winter use. Their pigs also eat the dead salmon washed ashore on the gravel banks of the stream. It is quite probable that the Indians and their pigs get enough iodine from the salmon to give their thyroids the necessary quantum of this element." [1]

Von Fellenberg, employed by the Swiss Goiter Commission to study the distribution of iodine in nature, found that foods from a goitrous territory contained less iodine than the same kinds from nongoitrous regions. He found milk (particularly milk fat), leafy vegetables, and fruits to be higher in iodine than other common types of food. Comparison of foods from goitrous and nongoitrous regions in this country have shown the same trends, as the following figures indicate.

Differences in Iodine Content of Foods from Goitrous and Nongoitrous Regions in Parts per Billion of Dry Substance

Food	Goitrous Regions	Nongoitrous Regions
Milk	190–260	900–1,170
Potatoes	85	226
Carrots	2	170
Wheat	1–6	4–9
Oats	10	23–175

Sea foods are all rich sources of iodine. Salmon, whether canned or fresh, ranges from 100 to 700 parts per billion of fresh substance, oysters average 492 parts, haddock 5,130 parts, and cod liver oil from 3,000 to 13,000 parts.[2]

[1] Keith, W. D. "Endemic Goiter." *Canadian Medical Association Journal*, Vol. 14, page 284 (1924).

[2] For other foods consult Sherman, H. C. *Chemistry of Food and Nutrition*, 5th edition. The Macmillan Co. (1937) and Coulson, E. J. *The Iodine Content of Some American Fishery Products*. Investigational Report No. 25, Bureau of Fisheries, U. S. Department of Commerce (1935).

From the earliest times it was popularly believed that the incidence of goiter was related to the water supply. Thus only did it seem possible to explain many instances of the close proximity of a goitrous to a nongoitrous region. Chemical evidence that this was not superstition or due entirely to other causes was afforded by a study of goiter by the Department of Health of the State of Michigan in 1924. "It was found that localities separated only a few miles varied in percentage of thyroid enlargements in native children from 10 to 100 per cent. One notable instance of this where there are sufficient children for a satisfactory random sample was in the difference in percentage of thyroid enlargement between Mount Clemens, which had 26 per cent, and Romeo, 12 miles distant, which had 75 per cent. Mount Clemens has an iodine content in the city water supply of approximately 25 parts per billion, while Romeo water does not contain a trace of iodine in 50 liters." [1]

McClendon and Hathaway have made a study of the iodine content of water from various parts of the United States and find that much of the northern half of the country falls into a low-iodine division with less than 23 parts per billion, in contrast to the southern half, with more than 23 parts per billion; the goiter incidence in the north is from 5 to 30 per 1,000 men, in the south from 0 to 5. Yet it is not the simple drinking of water which prevents goiter; even in the case of waters containing 10 parts per billion of iodine, 10 quarts of water would have to be drunk to get 0.1 of a milligram of iodine, the dose recommended for a school child. The iodine in the water is to be regarded as indicative of the iodine in the soils which come in contact with the water. Plants growing in the soils are the agency by which it is concentrated for human use. In regions which are nongoitrous, it seems highly probable that most persons may secure sufficient iodine by a liberal inclusion of milk and green vegetables in their diet.

[1] Olin, R. M. "Iodine Deficiency and Prevalence of Simple Goiter in Michigan." *Journal of the American Medical Association*, Vol. 82, page 1331 (1924).

The Requirement for Sulfur

Sulfur is a component of body protein occurring chiefly in the amino acids cystine and methionine. Sulfur in the form of cystine is also a component of the hormone insulin and of another chemical regulator of metabolism, glutathione. This latter substance, found and named by Professor F. Gowland Hopkins of Cambridge University in 1921, is present in many body tissues, and is an important factor in the control of the oxidative processes in the body. Sulfur in a form not hitherto known to occur in nature has been found to be an essential component of vitamin B_1 whose functions will be discussed in Chapter XI. Another sulfur compound, a derivative of histidine, called thioneine, is present in the blood corpuscles and undoubtedly plays an active part in nutritional processes.

Sulfur in food is found almost exclusively in the form of protein. Individual proteins differ considerably in their yield of sulfur, but the foods which ordinarily contribute most of the protein of the diet average about one gram of sulfur for each 100 grams of protein, or each 16 grams of nitrogen.

As the metabolism of sulfur usually runs somewhat parallel to that of nitrogen in the ratio of about one part of sulfur to 16 of nitrogen (corresponding to 100 grams of protein), we may assume for practical purposes that the sulfur requirement will be met when the protein intake is sufficient to meet the nitrogen requirement.

Requirements for Other Mineral Elements

The amount of sodium chloride taken in the form of common salt is so far in excess of human requirements for sodium and chlorine as to overshadow the latter completely in everyday life. Furthermore, these elements are so widely distributed in food materials that there is little likelihood of shortage of either unless some specially restricted diet is employed over a long period of time. The main question is whether or not sodium chloride will be used to excess.

There is a relation between the amount of salt and the amount of water retained in the tissues—the more salt the more water, and vice versa. In certain diseases affecting the circulation it is deemed desirable to restrict the amount of salt added to food in order to decrease the volume of fluid in the body.

Large amounts of salt also tend to stimulate the digestive tract and may thus interfere with the absorption of the food. For little children and invalids the use of foods preserved in salt is on this account objectionable. A good rule is probably to add always a little less salt than you would like.

Magnesium is so abundant in plant and animal foods that there is little likelihood of an insufficient supply in any ordinary mixed diet. A magnesium free diet is difficult to prepare, even for experimental purposes. Rats grow to maturity when very little is present in their food. That its presence is not without significance is indicated, however, by some experiments of McCollum and Orent with a practically magnesium free diet. On this the animals failed to grow, manifested skin disturbances and great nervousness, and there was loss of calcium from the bones and teeth, with marked changes in the dentine of the teeth and in their supporting tissues.[1]

Like magnesium, manganese is present in plant tissues generally, as well as in those of the animals which eat the plants, so that on an ordinary mixed diet there seems no likelihood of a deficiency in this element.[2] Of the manganese present in animal tissues, the highest concentration is in the liver.

On a diet of cow's milk supplemented with iron and copper, rats have been found to make better growth when manganese was added. Without the manganese there was a delay in sexual maturity and when the females finally bore young, these

[1] Klein, H., Orent, E. R., and McCollum, E. V. "Effects of Magnesium Deficiency on the Teeth and their Supporting Structures." *American Journal of Physiology*, Vol. 112, page 256 (1935).

[2] For manganese in foods, see Sherman, H. C. *Chemistry of Food and Nutrition*, 5th edition, page 594. The Macmillan Co. (1937).

were either dead or so weak that most of them did not survive more than a few days. Their bodies contained less than half as much manganese as those from mothers on a similar ration with added manganese. On a strictly manganese-free diet male rats became completely sterile because of degeneration of their testes and female rats refused to suckle their young. Addition of manganese to their diet resulted in normal development through several generations.

The body contains traces of fluorine and silicon, but their presence may be due merely to the fact that we can scarcely escape these elements which are present in our plant foods and in the dust which is constantly invading our bodies.

Any large amount of fluorine is certainly not desirable. McCollum and some of his associates, seeking to discover the cause of defective teeth in some of their laboratory animals, added a little over 2 per cent of fluorine to a diet which otherwise was known to produce good teeth. The result was disastrous. The incisors were misshapen, brittle, and occasionally mottled.

In certain sections of the United States a disease of human teeth characterized by mottled enamel is endemic.[1] Dull, chalky white patches appear on the surface of the teeth, and the enamel deteriorates. An intensive survey was made by Dr. Margaret Cammack Smith and E. M. Lantz of the University of Arizona [2] in St. David, Arizona, which showed that any child growing up in that town would have mottled teeth. By giving rats water from St. David wells, concentrated to one tenth its original volume, the same disease was produced in a month. That fluorine was the true cause was further shown by incorporating in a diet known to produce good teeth, small amounts of fluorine. Mottled teeth were the result.

[1] States in which mottled enamel has been reported include Arizona, Arkansas, California, Colorado, Idaho, Illinois, Kansas, Minnesota, New Mexico, North Carolina, North and South Dakota, Oregon, Texas, and Washington.

[2] Smith, M. C., and Lantz, E. M. *The Cause of Mottled Enamel, A Defect of Human Teeth.* University of Arizona Experiment Station, Technical Bulletin No. 32 (1931).

These findings of the laboratory are now fully confirmed in human experience, as is shown by what has happened in the town of Oakley, Idaho, since 1925. At that time every native child who had used the community water supply during the years of enamel formation was afflicted with this tooth disease. The water came from a warm spring and had a fluorine content of six parts per million. During that year a new water system was substituted, at a cost to the town of $35,000. This water had only one half part of fluorine per million. A survey seven and a half years later showed that no child whose teeth had developed since the change of water had mottled enamel. Fortunately, the amounts of fluorine in most food and water seem to be too small to have harmful effects.

Section 2

WATER

We have seen in Chapter VIII that water is an indispensable constituent of body tissues and that even a substance seemingly dry, such as bone, owes more than one third of its weight to water. Any considerable decrease in the normal amount of water in the body interferes with the manifold physical and chemical processes which are essential to life and health.

Rubner estimated that a man could lose practically all of his stores of glycogen and of fat and even half his protein without serious danger to life, but a loss of 10 per cent of body water is a serious matter and a loss of 20 per cent is scarcely to be endured.

The serious conditions brought about by severe and protracted vomiting or diarrhea, or by fever, are partly due to dehydration. Infants with nutritional disorders may lose water from the body to such an extent that the flow of digestive secretions is reduced and the condition of the intestinal canal altered, with the result that food cannot be digested and absorbed, and feeding does no good until some

means are found to restore the lost water to the tissues. Experimentally it has been shown that a dog fed a water free diet of dried meat and fat lost as much as 20 per cent of the water of his muscles in a few days and the food was regularly vomited because of the changes induced in the alimentary tract.

Certain insects can subsist upon food materials containing less than 10 per cent of water, i. e., as dry as a cracker, but these have a high energy metabolism and produce within their own bodies, through the combustion of their fuel foods, so-called metabolic water sufficient for their needs. Another interesting instance of meeting the body need for water by internal production is furnished by the camel, which, according to Babcock,[1] can go for long periods without drinking, more because of the fat of its hump and its carbohydrate food than because of the water in its stomach, the water formed in the process of food combustion being unusually well conserved by the coat of fine hair which reduces evaporation from the skin. Man, however, and most other large animals which excrete the nitrogenous products of their protein metabolism as urea, require a liberal supply of drinking water in addition to whatever they may acquire by metabolism or in food, to keep the urea content of blood and urine at a low concentration favorable to its excretion.

We must think of water in circulation as one of the conditions of health. Whatever its source, it is carried about and does its work without being chemically altered, again leaving the body as water, by way of kidneys, lungs, skin, and bowels. If we do not drink enough to make good the water loss the body soon ceases to function properly. Hawk states that in his laboratory normal young men put on a very low water ration soon gave evidence of abnormal function as shown by headaches, nervousness, loss of appetite, digestive disturbances, and inability to concentrate on their work, symptoms which were promptly relieved by

[1] For an excellent discussion of metabolic water, see Babcock, S. M. *Metabolic Water.* Wisconsin Agricultural Experiment Station, Research Bulletin No. 22 (1912).

increased water intake. Hawk has made an extensive investigation of the effect of water upon the digestive process in normal individuals, and finds that water upon reaching the stomach immediately stimulates the gastric glands to greater activity and in other ways improves digestion, while the dilution of the contents of the intestine by a liberal water intake facilitates the absorption of the digested food. He concludes: "The average normal individual will find that the drinking of a reasonable volume of water with meals will promote the secretion and activity of the digestive juices, and the digestion and absorption of the ingested food, and will retard the growth of intestinal bacteria and lessen the extent of the putrefactive processes in the intestine." [1]

Circulation of water is also essential to the elimination of waste from the body, and the freer this circulation the more readily are injurious products removed. It is better to have dilute than concentrated urine, both for the sake of the urinary tract itself and for the organism as a whole.

Of purely regulatory functions attributable to water the most conspicuous is related to the control of body temperature. The pathway for heat loss varies with the temperature of the environment; at low temperature there is little evaporation of water, but when the temperature of the air approximates or exceeds body temperature water evaporation must remove all the excess heat. In the normal resting man, at a temperature of 23° C. (73.4° F.) and medium humidity, about one fourth of the calories of the basal metabolism are dissipated through the evaporation of water as insensible perspiration and moisture from the lungs. This water, according to DuBois, amounts to about 700 grams ($1\frac{1}{2}$ lbs.) per day. Sweating promotes heat loss through evaporation if environmental conditions permit, and also favors conduction and radiation by increasing the moisture of the skin and perhaps of clothing. In a hot, dry atmosphere,

[1] Hawk, P. B. "Water as a Dietary Constituent." Barker's *Endocrinology and Metabolism*, Vol. 3, page 294. D. Appleton and Co. (1922).

the amount of water lost as perspiration is enormous. On the other hand, at a low temperature, sweating not only ceases but there is an actual mobilization of water from the blood into the tissues, so that less of it shall be brought to the surface to suffer cooling; thus the body heat is conserved.

Cannon sums up the case for water thus: "Water is the vehicle for food materials absorbed from the digestive canal; it is the medium in which the chemical changes take place that underlie most of our obvious activities; it is essential in the regulation of body temperature, and it plays an important part in mechanical services such as the lubrication of moving parts in the sliding of the intestinal coils on one another and the slipping of joint surfaces to and fro." [1]

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[1] Cannon, W. B. *Wisdom of the Body*, page 78. W. W. Norton and Co. (1933).

CHAPTER X

VITAMIN A AS A REGULATOR OF BODY PROCESSES

Discovery

A quarter of a century ago the word vitamin had just come into use. Today it is applied to those substances which occur in the most minute quantities in food and yet produce profound and specific physiological effects. They have been likened to the ignition spark of the automobile; they are, perhaps, more like the various hormones furnished to the body by the glands of internal secretion, such as thyroxin, insulin, cortin, parathormone, etc., each circulating in the blood in exceedingly small amount, but nevertheless powerful in its control of some function indispensable for life, health, and growth. The vitamins which we recognize today as essential in human nutrition are for the most part formed by green plants, and from them transferred to the bodies of animals. Only one, so far as known, can be developed within the human body, and even this synthesis is impossible without the external stimulus furnished by ultra-violet light.

The first experimental evidence that animals could not exist on mixtures of purified proteins, fats, carbohydrates, and mineral salts came from the laboratory of Dr. G. Bunge, professor of physiological chemistry in the University of Basel, Switzerland. In 1884 Lunin, one of his pupils, fed mice an artificial mixture of all the components of milk then known, but the animals failed to survive and Lunin concluded his report of the experiment thus: "A natural food such as milk, must therefore contain besides these known principal ingredients small quantities of unknown substances essential to life."

Bunge himself thought the real cause of the nutritional failure was some change in the form of the mineral elements which rendered them incapable of utilization by the animals and although another pupil, Socin, ten years later (1891) also became convinced that milk and egg yolk contained unknown substances of special significance for life and growth, no systematic search for them was instituted in Bunge's laboratory. "It is a noteworthy fact that, although animals can live on milk alone, yet if all the constituents of milk which according to the present teaching of physiology are necessary for the maintenance of the organism be mixed together, the animals rapidly die. Cannot cane sugar take the place of sugar of milk? Or are the inorganic and organic constituents of milk chemically combined, and only assimilable in this combination? On precipitation of the casein by acetic acid, the small amount of proteid in the milk remained in solution. Cannot this proteid be replaced by the casein? Or does milk contain, in addition to proteid, fat, and carbohydrates, other organic substances, which are also indispensable to the maintenance of life? It would be worth while to continue the experiments." [1]

In other parts of the world from time to time men found human diseases which could be cured by changes in diet, and laboratory workers sought animals in which similar diseases could be induced and then cured by the same foods which had proven efficacious for mankind.

In the United States, meanwhile, the agricultural experiment stations had taught farmers to "balance" the rations for stock, according to the "nutritive ratio," which meant the ratio between calories from protein on the one hand and from carbohydrate and fat on the other. But Professor S. M. Babcock, at the station established at the University of Wisconsin, determined to test rations balanced according to approved standards but derived from different plant sources, to see whether there might be any difference

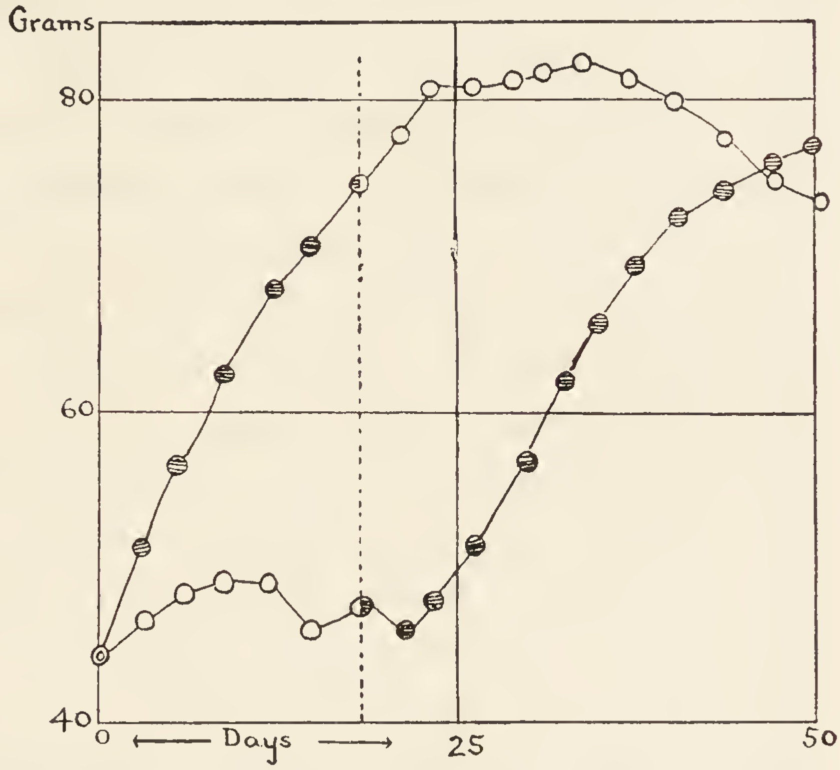
[1] Bunge, G. *Text-book of Physiological and Pathological Chemistry*, page 89. P. Blakiston's Son and Co. (1902).

in their nutritive value. With the coöperation at first of Hart and Humphrey and later of Steenbock and McCollum, an experiment was conducted on groups of young heifers, one group being fed a wheat plant ration (wheat straw, wheat gluten, and entire wheat grain); another a corn plant ration; a third an oat plant ration; and a fourth a ration drawn from all three plant sources. All groups ate practically the same amounts of food and digested their rations equally well. For the first year of the experiment there was little to distinguish one group from another, but gradually the corn fed group grew smoother in the coat and fuller in the barrel, while the wheat fed group became rough of coat, gaunt and thin, and small of girth. The groups on the oat plant ration and the mixed ration stood intermediate between the corn fed and the wheat fed animals.

In addition to these outward signs there was a startling evidence of nutritive differences among the rations in the reproductive capacity of the animals. On the corn plant ration the young were carried to full term, were able to stand and suck an hour after birth, and grew normally. On the wheat plant ration the young were born prematurely, were small and weak and, if not stillborn, died within a few hours. The young of the oat fed mothers weighed nearly as much as those from the corn fed mothers, but were all born prematurely and either dead or so weak that they died in a short time; only one, very feeble, was kept alive by very special care. The mixture of grains did not prove as satisfactory as the corn alone. McCollum said, in reviewing this work: "It was not possible by any means known to biological chemistry to work out a reason as to the cause of the pronounced differences in the physiological well-being of the different lots of cows."

One of the first persons to appreciate the full significance of the failure to attain normal nutrition on purified proteins, fats, carbohydrates, and minerals and the amazing success of adding minute quantities of unknown substances present in natural food appears to have been Professor F. Gow-

land Hopkins of Cambridge University. Although he did not venture to print the results of his own experiments until 1912, as early as 1906 he sounded the modern note. "No animal can live upon a mixture of pure protein, fat and carbohydrate, and even when the necessary inorganic material is carefully supplied, the animal still cannot flourish. The animal body is adjusted to live either upon plant tissues or other animals and these contain countless substances other than the proteins, carbohydrates and fats. . . . Scurvy and rickets are so severe that they force themselves upon our attention but many other nutritive errors affect the health of individuals to a degree most important to themselves and some of them depend upon unsuspected dietetic factors." [1]



(*Courtesy of Dr. F. G. Hopkins*)

FIG. 53.—The Effect upon the Growth of Young Rats of Adding a Small Amount of a Food Containing Vitamins to a Diet of Purified Food Materials.

The lower curve (up to the 18th day represented by the dotted line) shows the average weight of 8 rats upon the purified food. The upper curve, 8 similar rats taking 3 cc. of milk daily. On the 18th day, the milk was transferred from one set to the other.

Hopkins fed young rats a diet of casein, lard, starch, cane sugar, and mineral salts obtained by mixing equal parts of ash of oats and dog biscuit. When these substances were highly purified in the laboratory, growth was arrested and decline and death speedily ensued, even though the food intake appeared sufficient. When to the purified ration were added only two or three cubic centimeters of milk daily—less than one third of a teaspoonful—growth was promptly resumed, as shown in Fig. 53.

[1] Hopkins, F. Gowland. "Analyst and the Medical Man." *Analyst*, Vol. 31, page 385 (1906).

About the time that Hopkins was beginning this work, Osborne and Mendel in New Haven were initiating an investigation of the influence which proteins unlike in their chemical make-up might have upon nutritive processes. They devised a ration in which all the dietary needs were met save that for protein, in order to add proteins from different sources and study their effects. These investigators, too, found difficulties in using highly purified fats, carbohydrates, and mineral salts, and ere long (1911) devised a preparation of milk freed of its casein, albumin, and fat, which they called "protein-free milk." By adding this to mixtures of pure starch, sugar, and fat along with any pure protein to be investigated, they were able to keep white rats alive through longer periods of time than had ever before been possible, but they found that beyond periods of about 100 days little or no increase in body weight could be induced, although the animals remained for some time in good condition.

When whole milk powder was substituted for the casein and protein free milk they were able to bring young animals through two generations. They concluded that the essential difference between the two diets lay in the milk fat. When, accordingly, butter was substituted for lard in the protein free milk food, growth was promptly resumed and adult size attained.

While these experiments were going on in the New Haven laboratories, progress in growth control was also being made in Wisconsin. McCollum and Davis, meeting similar difficulties in promoting growth on rations of purified casein, carbohydrates, lard, and various salt mixtures, found that resumption of growth occurred promptly when an ether extract of egg or butter was added.

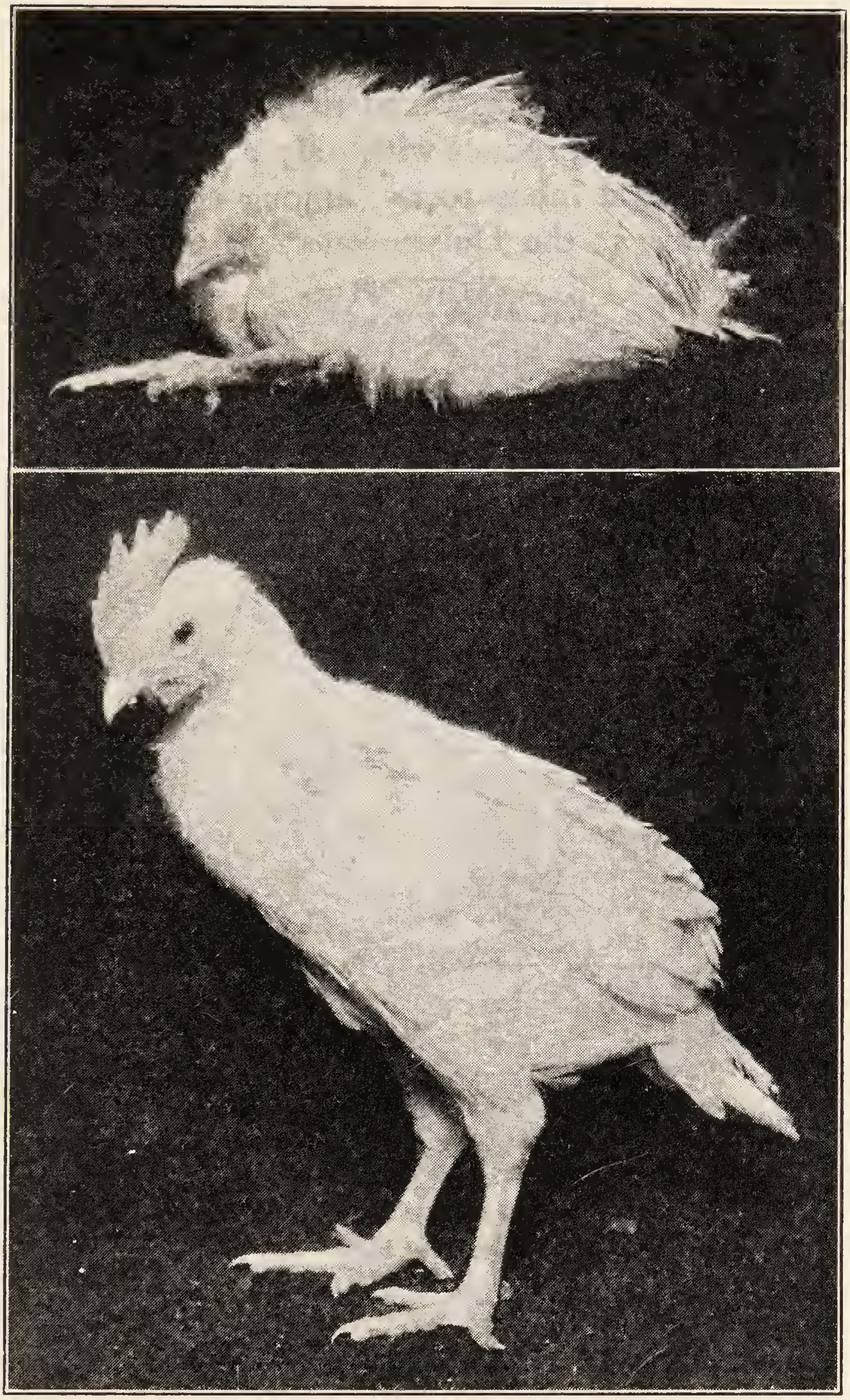
Thus two different laboratories, attacking the problem from quite different angles, simultaneously discovered that there is something in butter fat and egg yolk not found in lard and common vegetable fats which is essential for growth and which cannot be manufactured by the animal organism. This substance is now known as vitamin A.

The search for vitamin A in foods went forward by leaps and bounds after 1913. Not only fish liver oils, eggs, and butter, but also green leaves and yellow parts of plants proved to be excellent sources. Carrots and sweet potatoes were found to be rich sources of the vitamin while white turnips and Irish potatoes furnished practically none. In 1919 Professor H. Steenbock at the University of Wisconsin, finding that yellow corn could be used as the only source of vitamin A in the diet of young rats with excellent results, while white corn was very deficient, called attention to the remarkable coincidence in the occurrence of the yellow coloring matter of plants and the success in nutrition when they were used to furnish vitamin A. He extracted some of the pigment of carrots, known as carotene, crystallized it, and found that the crystals had vitamin A activity. But other workers had experiences which did not accord with this point of view. Various kinds of fat which contained no yellow pigment cured xerophthalmia and promoted growth, and hens with no carotene in their food laid colorless eggs rich in vitamin A. Rats were successfully raised on a diet in which the pigment free eggs were the only source of the vitamin and not a trace of yellow pigment could be found in their bodies. For a time it seemed settled that carotene had no connection with vitamin A, but in 1928 Professor Hans von Euler of the University of Stockholm prepared some very pure carotene crystals and again tried feeding them to young rats, in a diet otherwise devoid of vitamin A, this time with success, as little as five thousandths of a milligram being sufficient for good growth. When a little later Dr. Thomas Moore of the Nutritional Laboratory in Cambridge, England, cured xerophthalmia in a rat equally well by one tenth of a gram of fresh carrot, or four ten thousandths of a gram of oil from the carrot, or one hundred thousandth of a gram of highly purified carotene, it seemed quite clear that Steenbock was right in 1919 in thinking that there was a close connection between the yellow color of foods and vitamin A.

In many parts of the world, interest in the relationship between carotene and vitamin A became very keen. In Paris, in 1932, a sample of carotene made from spinach forty years previously and kept in a sealed tube as a museum specimen was brought forth and a portion fed to vitamin A deficient rats, with the same success that had attended Steenbock and Euler's experiments. At the University of Wisconsin, Hart and some of his co-workers using chicks, which also require vitamin A, compared the effect of two kinds of plant coloring matter in spinach, one being carotene and the other a related substance known as xanthophyll. All the chicks grew well for about four weeks, then those on the vitamin A free diet developed severe symptoms of vitamin A deficiency. Growth ceased, feathers became ruffled, a staggering gait developed, then the birds finally appeared drowsy and lay over on one side. In a few days they were dead. Those given xanthophyll were no better off, but those given as little as 0.00003 gram of carotene per day grew at a normal rate and remained in excellent health. The difference is shown in Fig. 54.

Thus evidence accumulated that carotene is the substance out of which the body can, when necessary, manufacture vitamin A and consequently it is often referred to as the pro-vitamin A. Preparation of carotene crystals on a commercial scale has now made them available at low cost. There are three common forms, differing only slightly in chemical constitution, and distinguished from one another as alpha, beta, and gamma carotene. All three yield vitamin A but beta carotene twice as much as either of the others. A definite weight of beta carotene, 0.0006 milligram, is now an international standard for the measurement of vitamin A values.

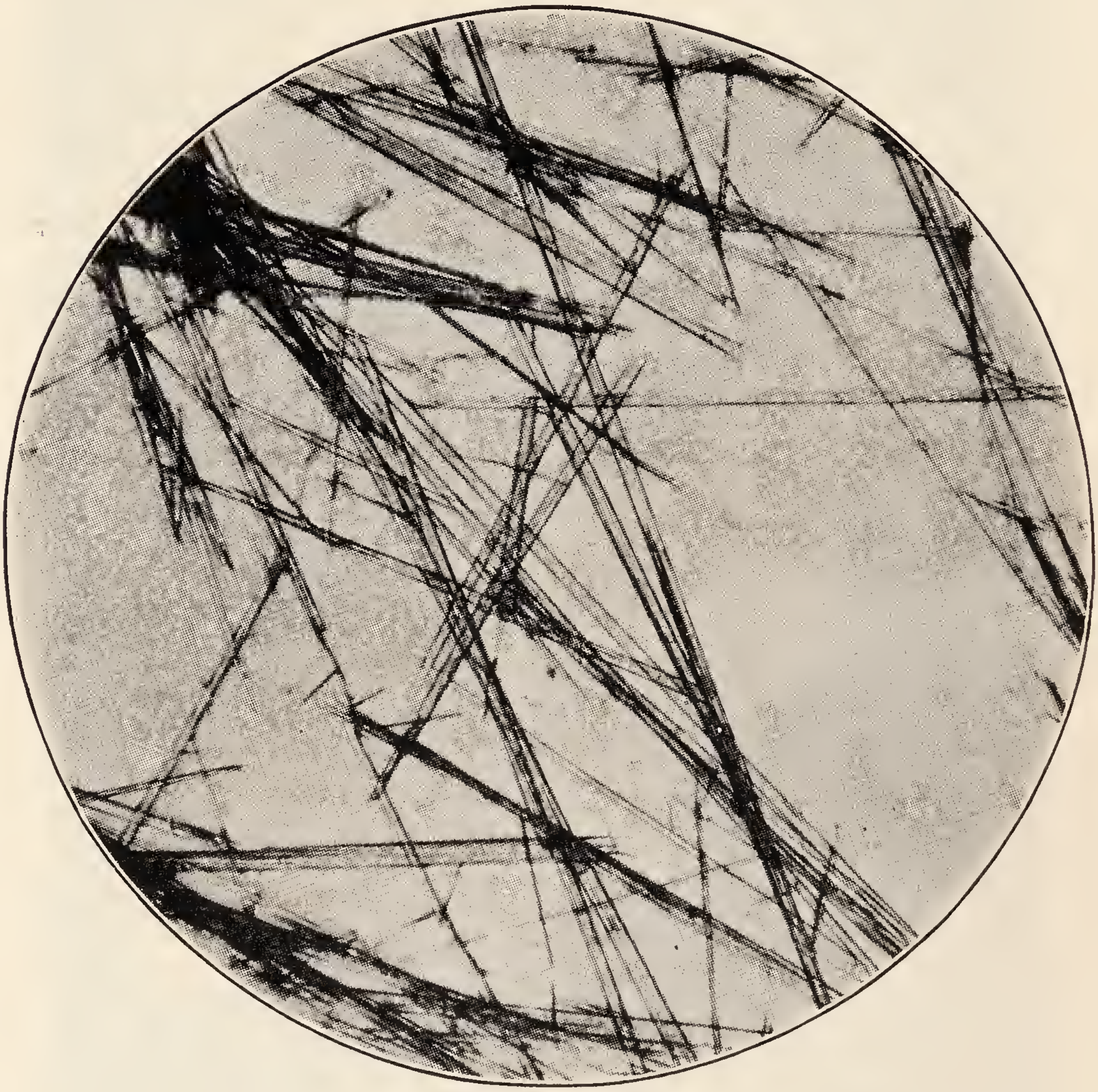
When cod liver oil was discovered to be a rich source of vitamin A, other fish oils were also investigated and some of them found to be amazingly rich in this vitamin. Among them, halibut liver oil proved an easily available source of material from which to try to isolate the vitamin in pure form. The first step is to remove the fat, which is the main



(*Courtesy of Professor E. B. Hart*)

Fig. 54.—The lower chick received 0.03 mg. carotene daily in addition to a basal diet adequate in all respects except vitamin A. It exhibited no vitamin A deficiency and weighed 320 grams at five weeks. The upper chick received 0.25 mg. xanthophyll daily in addition to the basal diet. It developed symptoms characteristic of vitamin A deficiency and weighed only 160 grams at five weeks.

part of the natural product, and then to find means of separating the vitamin from the waxy constituents in the residue. This problem has taxed the skill of many investigators, but finally a product with only a little impurity was prepared in several laboratories, among them that of Professor P. Karrer at the University of Zurich, Switzerland.



(*Courtesy of Professor Harry N. Holmes and the New York* Herald Tribune)
FIG. 55.—Crystals of Pure Vitamin A.

This vitamin A concentrate was a slightly yellow, oily substance giving certain well established tests for vitamin A, and from it Professor Karrer was able to determine the chemical constitution in 1933.[1] Crystallization of the vitamin was now the goal, the problem being to find a means of removing the last trace of impurity. In 1934 Professor H. N. Holmes of Oberlin College was able to report a product

[1] The numerical formula is $C_{20}H_{30}O$; the structural formula can be found in Sherman's *Chemistry of Food and Nutrition*, 5th edition, page 352. The Macmillan Co. (1937).

almost 100 per cent pure having as high as 14,000 times the potency of standard cod liver oil, but it took nearly three more years of effort to achieve complete success. In the latter part of 1936 he was able to show the first pure, pale yellow, needle-like crystals of vitamin A,[1] prepared from the liver oil of Atlantic Ocean mackerel, and a little later obtained others from a Japanese fish, *Stereolepis ishingi*. Samples of these crystals were sent to three other laboratories where their biological activity was tested and reported to be about 3,000,000 international units per gram.

The Promotion of Growth

As already stated, vitamin A was discovered through the failure of rats to grow for more than 70 to 120 days on

FIG. 56.—These two rats are the same age. The lower one had an adequate diet, the upper one a diet lacking vitamin A.

rations adequate in protein, mineral salts, and the vitamin B complex, and their prompt resumption of growth when butter fat or an ether extract of egg yolk was added to the ration. At first there was much irregularity in the time required by different animals to show signs of vitamin A defi-

[1] Holmes, H. N., and Corbet, R. "A Crystalline Vitamin A Concentrate." *Science*, Vol. 35, page 103 (1937).

ciency, but it was soon realized that if the animals placed upon the vitamin A free diet had been previously fed one rich in it, they continued to grow for a much longer time than those whose former diet had been good in all other respects but low in vitamin A. Typical growth curves for

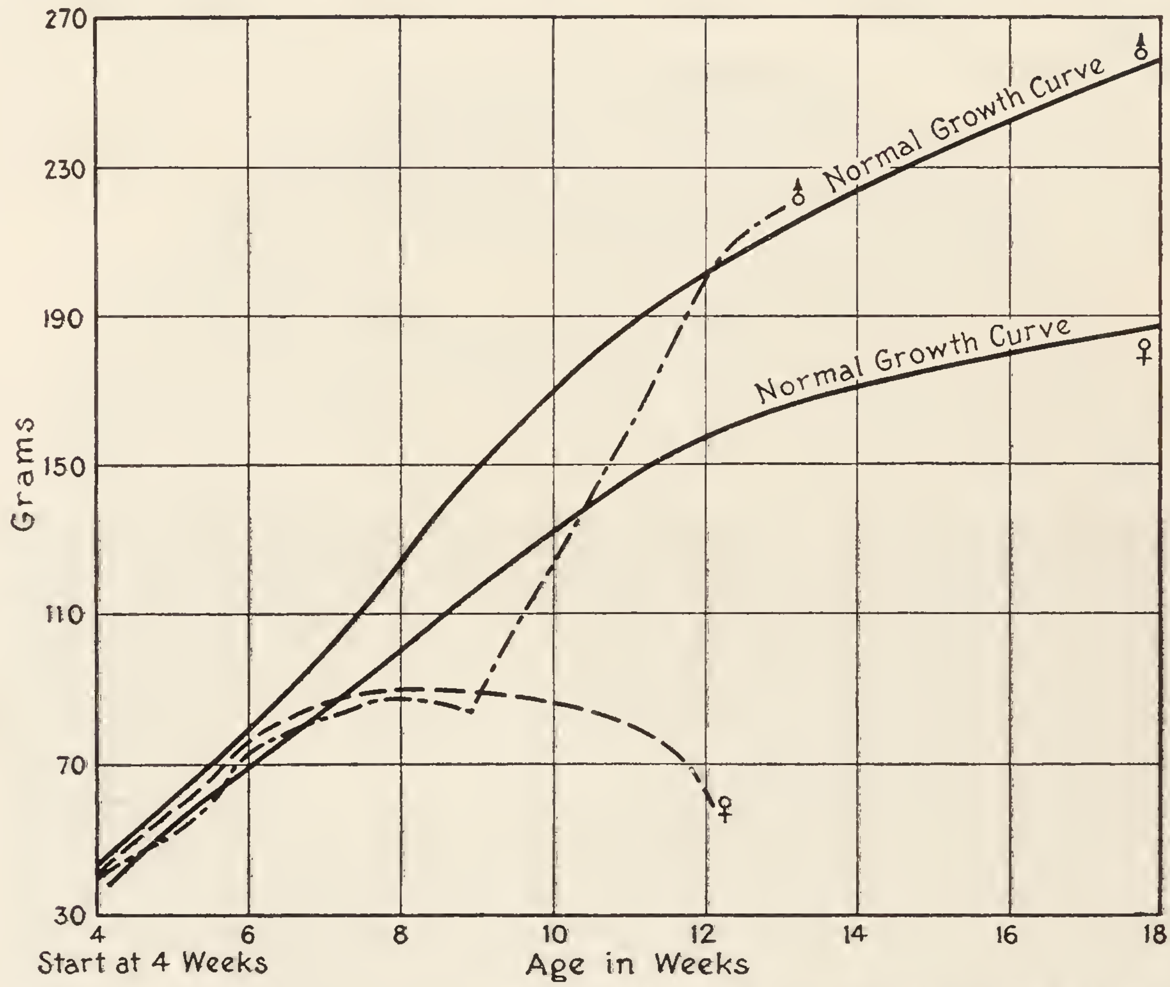


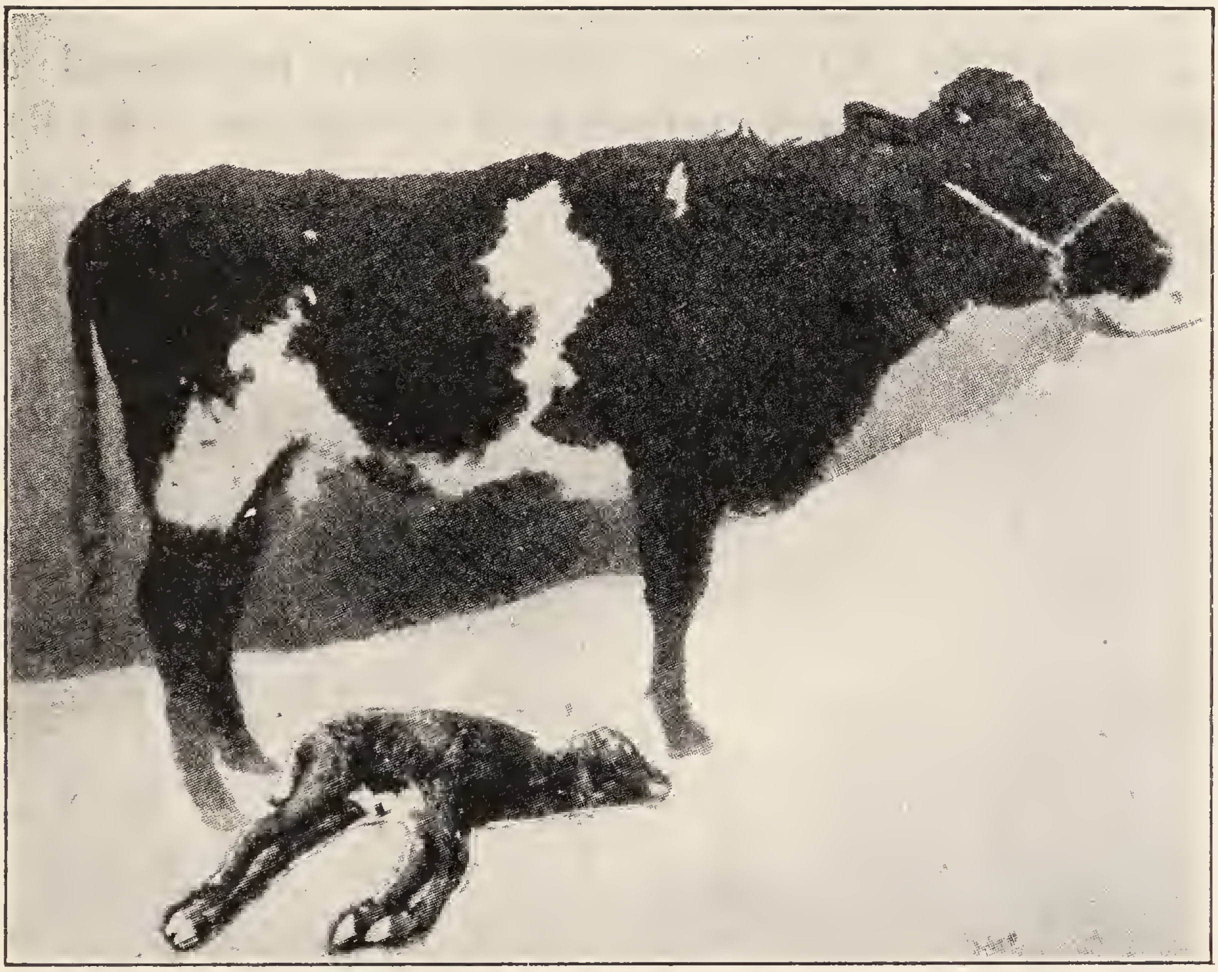
FIG. 57.—Growth of rats on a vitamin A free diet compared with that of rats of the same age on a normal diet. When vitamin A was added to the diet of the male after 5 weeks deprivation, it doubled its weight in $2\frac{1}{2}$ weeks. The female, given no vitamin A, continued to lose weight and died.

young rats, weaned at the age of four weeks from a mother on an adequate diet, and placed on a diet entirely free from vitamin A (Fig. 56), indicate how growth continues until the vitamin A reserves of the body are exhausted. If the vitamin is not added to the diet when growth ceases, symptoms of deficiency soon become marked and death ensues, but if the vitamin is supplied growth is promptly resumed as shown in Fig. 57.

Reproduction and Lactation

After the vitamin B complex had been discovered and attempts were being made to rear animals on diets of purified

casein, lard, cornstarch, and mineral salts to which a daily portion of yeast was added, it was found that, while the young animals grew for some time at a good rate, they matured late and were frequently sterile or else bore offspring so feeble that they soon died. This type of diet contained little if any vitamin A. Upon the discovery of the existence



(From Research Bulletin 17, University of Wisconsin Agricultural Experiment Station)

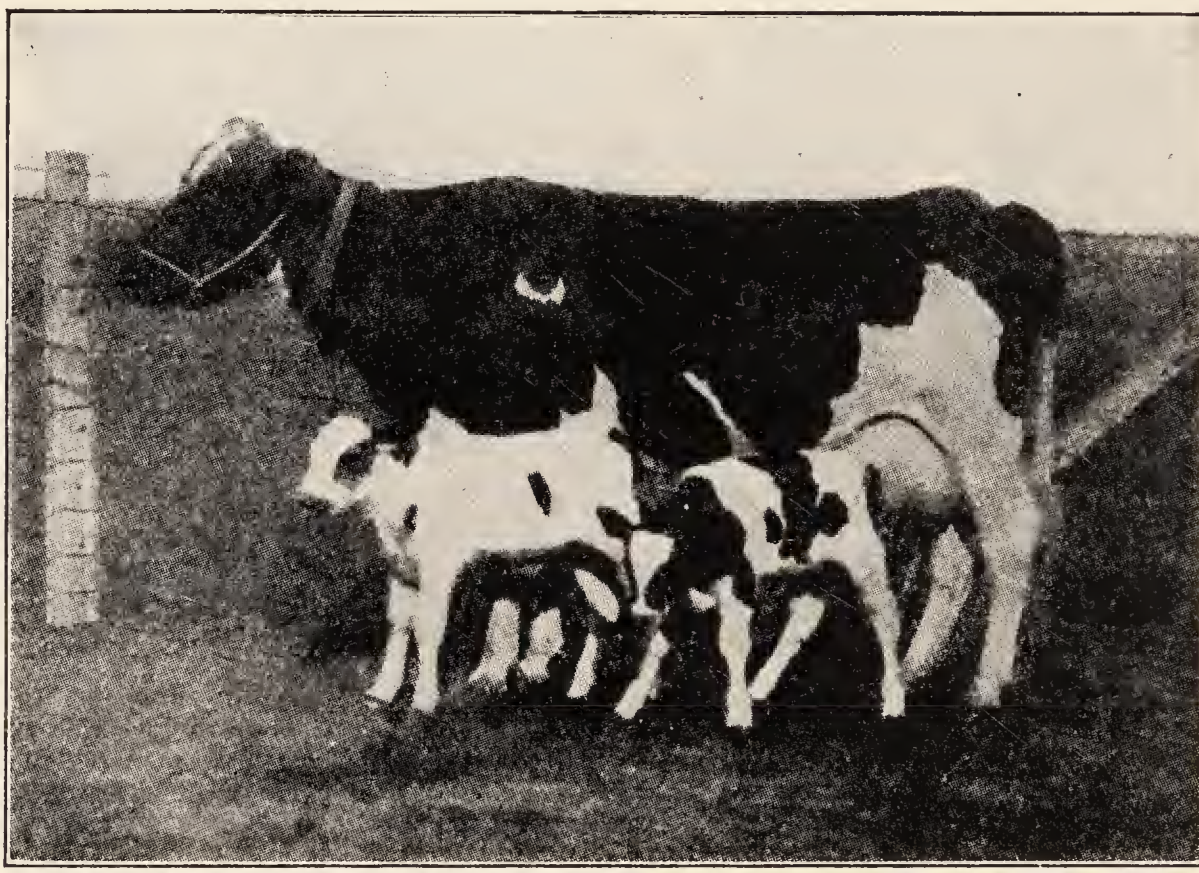
Fig. 58.—In 1907, feeding a ration made from wheat straw, wheat meal, and wheat gluten, with common salt, resulted in nutritional disaster. The cow was shaggy-coated, slow and sleepy in movement, and had a tendency to drag her hind feet. The calf was born prematurely and died.

of vitamin A and the substitution of butter fat for part of the lard, it became possible not only to secure growth to full maturity but also to obtain a second generation of animals and bring them, too, to successful reproduction.

In the classic Wisconsin experiment with rations derived from a single plant source, the most unexpected result was the difference in the reproductive capacity of the cattle on the different diets. Normal young could not be produced on the wheat plant ration; the estrus cycle was delayed and in some individuals never appeared. Where the estrus cycle

did appear, the offspring were stillborn or died soon after birth. On the corn ration the reproduction cycle was complete, and where yellow corn grain was substituted for the wheat grain in the wheat plant ration, to which a mineral salt mixture containing calcium had been added, reproduction again became normal. It was not then known that yellow corn contained vitamin A.

In 1924, the Wisconsin experimenters rebalanced the wheat plant ration and corrected its deficiencies in the light



(*Courtesy of Drs. E. B. Hart and H. Steenbock*)

FIG. 59.—In 1924, when the ration of 1907 was supplemented with bone meal 2 per cent, common salt 1 per cent, and raw cod liver oil 2 per cent, its deficiencies were fully corrected. This cow was in excellent condition and produced twins weighing 124 pounds.

of our present knowledge. To the original ration of wheat meal, wheat gluten, and wheat straw, they added 2 per cent of bone meal for calcium phosphate, 1 per cent of common salt (as wheat is low in chlorine), and 2 per cent of raw cod liver oil. No more beautiful demonstration of the triumph of dietary knowledge can be found than in the contrast between the wheat fed cow and calf of 1907 and those of 1924 (Figs. 58 and 59).

The way in which vitamin A functions in reproduction was made the subject of special investigation by Evans and his associates in the Department of Anatomy of the University of California, who found that a characteristic disturbance of the estrual cycle with consequent failure of ovulation occurs in 100 per cent of animals reared on diets low in vitamin A and yet containing enough to permit approximately normal growth.

The interference with reproduction caused by lack of vitamin A is unlike that brought on by any other kind of dietary deficiency, and is cured by raising the amount of A to a higher level. This has been demonstrated by Sherman and MacLeod, who took two groups of rats from mothers on an adequate diet and fed them diets alike in all other respects, but one low, the other high in vitamin A. The diet with the lesser amount of A proved sufficient for normal growth up to nearly average adult size, but not for successful reproduction. The animals receiving the more liberal allowance of vitamin A grew to fully average adult size, and their success in reproduction is admirably typified by a comparison of twin sisters on the two diets, as shown on page 103.

The vitamin A content of milk is influenced to some extent by the vitamin A content of the diet. Butter made from the milk of cows on a ration of ground oats and barley, wheat middlings, timothy hay, and oat straw contains less vitamin A than that from milk of cows whose dry feed is supplemented by summer pasture. "June butter" is better in vitamin A value as well as in color and flavor. Average human milk, pooled from many individuals, has been found to be relatively richer in vitamin A than in vitamin B, but the milk of a mother whose diet consisted largely of tea and toast was inadequate to prevent signs of vitamin A deficiency when fed to rats as the sole source of the vitamin.

Doctor W. J. Dann of the Nutritional Laboratory at the University of Cambridge found that the amount of vitamin A in the livers of young rats was definitely influenced by

controlling the amount of carotene given to the mother. When the mother's diet was rich in carotene, the amount of vitamin A in the young rat's liver was three times as great as when the mother's diet was completely lacking in carotene (or vitamin A). When the mother received throughout pregnancy and lactation a diet free from carotene and vitamin A, no measurable amount of vitamin A could be found in the livers of the young at weaning time. The amount of vitamin A which can be transmitted from mother to offspring is, however, not large, and the best way to insure adequate reserves of vitamin A in the nursling is to administer it directly to the child in addition to a good supply for the mother.

Resistance to Infection

The ability of the animal body to store vitamin A becomes apparent when young rats at weaning time are placed on diets lacking this vitamin. The length of time during which they continue to grow will depend upon the store which they have previously received. But a surplus of vitamin A in the body is not simply a reserve for some future time of shortage. It is at all times significant for the maintenance of resistance to disease and the development of a high degree of physical vigor. During the past decade a great deal of experimental evidence has been obtained regarding the character of the changes which lack of vitamin A induces in the various tissues of the body and it has become very clear that the health of the epithelial cells, found in the skin and in the mucous membrane in all its ramifications through the respiratory tract, the digestive system, the genitourinary system, the ducts leading from all sorts of glands, and the inner surfaces of many glands are very quickly altered by deficiency of this vitamin. In the sections which follow, the effects of these epithelial changes in various parts of the body will be discussed.

Long before any symptoms of disease are apparent, an examination under the microscope of a few cells scraped

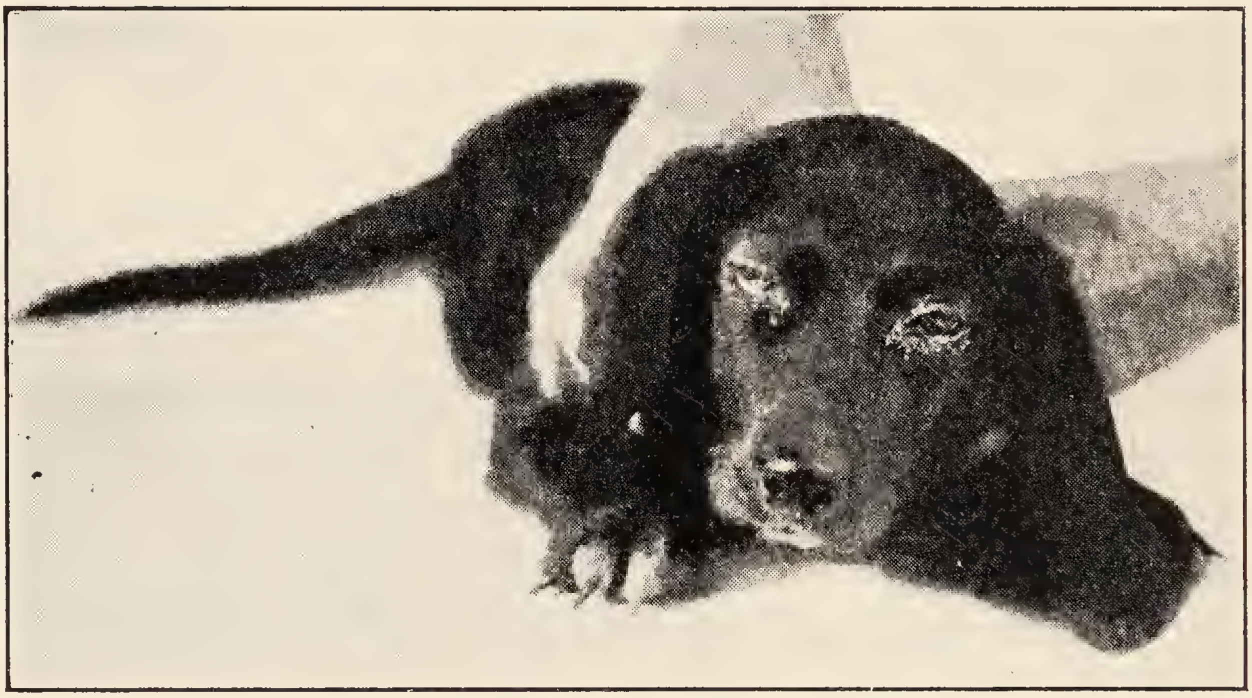
from the mucous membrane will disclose the drying and deterioration which are incident to the process known as keratinization; or histological examination of the ducts of the sublingual glands, the sebaceous glands of the skin or of the various lachrymal glands of the eye will show them choked with masses of dead cells which have been thrown off from the mucous surface and remained to obstruct the passage. The mucous membrane being thus deprived of its normal secretion offers a good harbor for chance micro-organisms which would ordinarily prove harmless. Local infections occur and the bacteria may even penetrate through the walls of the injured membrane which is no longer able to resist their invasion. An adequate vitamin A supply at all times is a means of strengthening the natural defenses of the tissues. After damage due to an inadequate supply has been done, dosing with the vitamin will not guarantee a cure, although it may help to hasten such recovery as the tissues are still capable of. Doctor S. W. Clausen of the University of Rochester School of Medicine, studying the influence of vitamin A upon infection in infants found that among 317 under 36 months of age severe infections were twice as frequent in those whose previous diet lacked vitamin A as in those to whose diet it was added in the form of cod liver oil from the age of three months and also in the form of vegetables containing carotene from the age of six months.[1]

Xerophthalmia and Night Blindness

As soon as vitamin A was recognized as a definite factor in growth (1913) and experiments to determine the effect of withholding it from the diet were initiated, the observation was frequently made that the animals developed a characteristic eye disease. In this the lachrymal gland ceases to function; the eyeball becomes dry and bacteria quickly begin to grow in the conjunctival sac; the lids of one or both eyes become congested, an exudate comes from the

[1] Clausen, S. W. "Nutrition and Infection." *Journal of the American Medical Association*, Vol. 104, page 793 (1935).

inflamed conjunctiva; and soon the swollen, sticky, and scabby lids completely close the eye. If not arrested, the disease eventually attacks the cornea and permanent blindness ensues, unless the animal die before this stage be reached. This disease is variously known as xerophthalmia, keratomalacia, or conjunctivitis. The relation of the diet to the disease was discovered by Osborne and Mendel,



(Courtesy of Drs. H. Steenbock, V. E. Nelson, and E. B. Hart)

Fig. 60.—Xerophthalmia in the Dog.

who in 1921, reviewing their experiences with this disease, gave the following report of practically all the rats under observation in their laboratory for one year.

Incidence of Xerophthalmia in 1,000 Rats

	Total Number of Rats	Number with Eye Symptoms
On diets deficient in vitamin A	136	69
On diets deficient in vitamin B	225	0
On diets otherwise deficient	90	0
On diets experimental but presumably adequate	201	0
On mixed food (stock animals)	348	0
	1,000	69

These laboratory experiences with the white rat stimulated inquiry as to the effect of withholding vitamin A

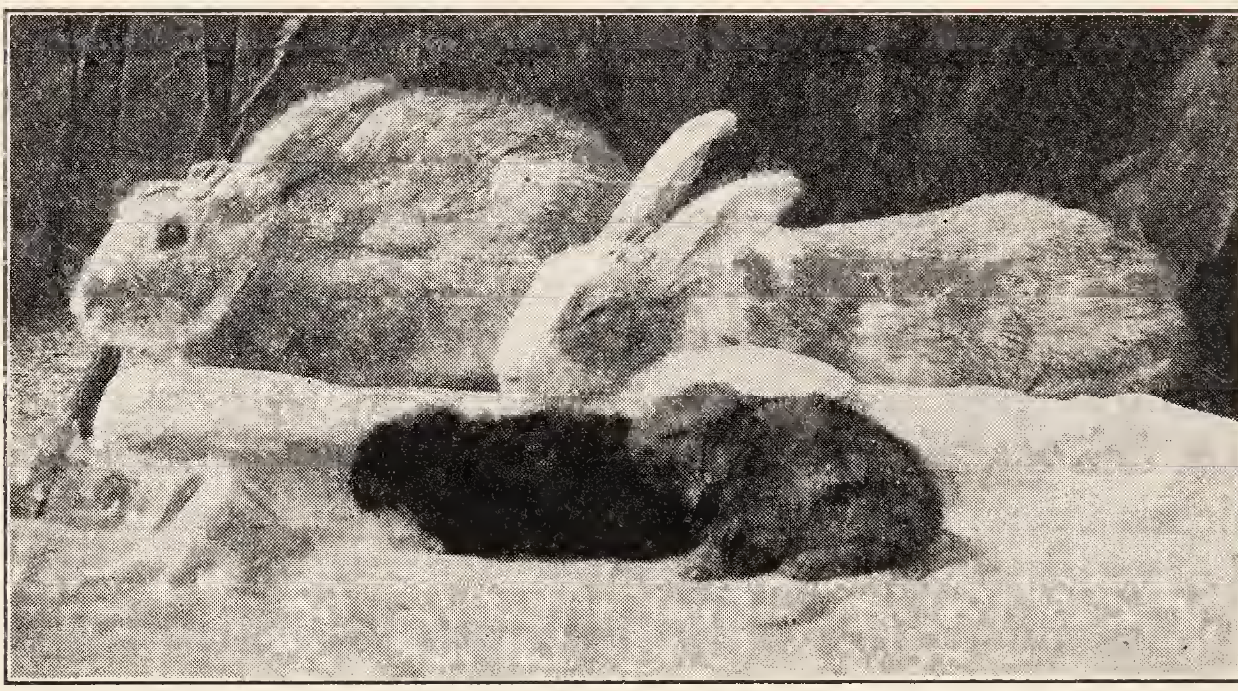
from other species of animals, and xerophthalmia has been experimentally produced in dogs, rabbits, mice, horses, swine, guinea pigs, chickens, and monkeys.

Such experiences inevitably turned attention to eye disease occurring in the human race, with a view to its possible correlation with dietary deficiency. Diseases of the eye have afflicted mankind since time began and are mentioned in the ancient medical literature of Egypt, China, and Greece, but the first person of modern times to show a definite connection between xerophthalmia and diet appears to have been a Japanese physician named Mori, who published in German a report of the so called "Hikan," an eye disease of which, at a time of food shortage, he had observed nearly 1,500 cases among children from two to five years of age. This he believed to be due to the lack of fat, as it was curable (if it had not progressed too far) by the administration of chicken livers, fish livers, or eel fat, and also of cod liver oil, all of which are rich in vitamin A.

Other illuminating experiences were recounted thirteen years later (1917) by Dr. C. E. Bloch [1] of Copenhagen, who had personally observed during the years from 1912 to 1916 many cases of xerophthalmia among children of the Danish poor. The most severe cases were among children about a year old, who had been fed chiefly skimmed milk practically free from fat, along with oatmeal and barley soup, and who were threatened with blindness owing to ulceration of the cornea. As the children were greatly undernourished, whole milk was prescribed together with liberal doses of cod liver oil. The result was a rapid disappearance of the eye trouble and a complete cure whenever the destruction of the cornea had not gone too far. In 1918, upon the introduction by government action of butter into the dietary of the poorer people, xerophthalmia was practically wiped out of Denmark. It is still prevalent in the Far East, where the diet of the poor is usually very low in

[1] Bloch, C. E. "Eye Disease and Other Disturbances in Infants with Deficiency of Fats in the Food." *Journal of the American Medical Association*, Vol. 68, page 1516 (1917).

vitamin A. In the clinic of the Peiping Union Medical College in China, out of 154 patients with this disease whose diets were known, 29 had no apparent source of the vitamin and 110 practically none except what they obtained from white cabbage.[1] In 1930 there were found in this clinic 116 cases of xerophthalmia, representing over one third of all the cases of that year suffering from blindness. In



(Courtesy of Dr. V. E. Nelson)

Fig. 61.—Xerophthalmia in the Rabbit.

The eye disease developed in the mother (right) as the result of bearing the young on a ration deficient in vitamin A.

harmony with laboratory experience with animals, the greatest sufferers are the children, although another rise in the incidence of the disease comes in early adult life when hard work and poor food undermine health. Not only in China but also in India and Ceylon it is the chief cause of the many cases of blindness among children. The dryness of the eyes is such that the children are very often seen moistening their eyes with saliva.

The onset of xerophthalmia is brought about in many cases on the borderline of vitamin A deficiency by the onset of some other disease, especially dysentery and other infections of the intestinal tract, which are exceedingly common in the Orient.

[1] Sweet, L. K., and K'ang, H. J. "Clinical and Anatomic Study of Avitaminosis A among the Chinese." *American Journal of Diseases of Children*, Vol. 50, page 699 (1935).

Night blindness, or hemeralopia, the inability to see clearly in a dim light especially after exposure to an intense one, has been observed wherever xerophthalmia has occurred. Thus slaves in Brazil, according to an 1883 report, were unable to see when returning from their work after sunset, although strangely enough they had no difficulty in setting out again before sunrise in the morning when it was actually much darker than on the previous evening. This disease is now known to have the same cause as xerophthalmia, lack of vitamin A in the diet.

This was beautifully demonstrated by Professor L. S. Fridericia and Dr. E. Holm at the University Institute of Hygiene in Copenhagen in 1925. The disease was at that time known to be due to an anomaly in the rod cells of the retina, which consisted in inability of visual purple which is bleached in light to regenerate quickly. So these investigators set out to compare the visual purple in the retinas of normal rats with those of rats given a diet lacking vitamin A to see whether this lack was the cause of the difficulty. When the growth curves showed that the vitamin A reserve was exhausted and before any other symptoms of deficiency appeared, the depleted animals were taken from a dark room and exposed to a brilliant light, by which the visual purple was completely bleached in two hours, the same time required for bleaching in case of the normal controls. Measurements of the visual purple showed that the time in which the color was completely regained when they were returned to the dark room was very much shorter in the normal animals than in those deprived of vitamin A. When it was learned that the retina is rich in vitamin A, the value of tests of speed of recovery of the visual purple after exposure to light as a means of detecting vitamin A deficiency began to receive special attention. During the World War an ophthalmologist, Birch-Hirschfeld, had devised a test for measuring the impairment of vision in a dim light of soldiers in the German army, and this was in 1934 adapted by Jeans to the study of the eyes of school children as a

possible means of determining their vitamin A reserves, its practicability resting upon the fact that slowness in regeneration of the visual purple is one of the common early symptoms of vitamin A deficiency. The test was applied to a large number of Iowa school children, in rural, village, and urban homes, on different economic levels. The findings are shown in the following table.

Responses of School Children to a Test for Adaptation to Darkness [1]

Economic Level	No. Examined	Per Cent Definitely Subnormal
Middle to low (rural)	100	26
All levels (village)	102	53
Upper level (urban)	70	56
Middle level (urban)	70	63
Lower level (urban)	70	79

As far as possible halibut liver oil or carotene in oil equivalent to 3 teaspoons of cod liver oil was administered each school day by the teachers for several weeks to those showing poor adaptation. Of 78 children so treated all but three recovered normal sensitivity, the majority within a month. Similar studies in Canada, Sweden, and Denmark indicate that many children who appear perfectly normal are not having as liberal amounts of vitamin A as are necessary to keep the visual purple of the retina functioning at its best at all times.

The Respiratory Tract

The changes in epithelial tissue when vitamin A is lacking have nowhere been more clearly demonstrated than in the mucous lining of the respiratory tract. Here, in addition to the shrinking, hardening, and general deterioration of the cells, resulting in dry, roughened surfaces lacking their normal protective secretions, there is also loss of the cilia which by their constant movement aid in keeping the surfaces clean. In the very detailed studies of vitamin A deficiency in China made by Sweet and K'ang, the most

[1] Jeans, P. C., and Zentmire, Z. "The Prevalence of Vitamin A Deficiency Among Iowa Children." *Journal of the American Medical Association*, Vol. 106, page 996 (1936).

frequent symptoms, next to those in the eye, were found in the larynx and the trachea and sometimes even in the bronchi. In studies in this country on infants, Dr. S. B. Wolbach of the Harvard Medical School, to whom much of our knowledge of the influence of vitamin A on epithelial cells is due, and Dr. K. D. Blackfan, a leading pediatrician of the same school, also noted that the earliest appearance of keratinization was in the upper part of the respiratory tract.[1]

These human findings are in agreement with many observations on laboratory animals under carefully controlled conditions. As long ago as 1923, Dr. Amy L. Daniels of the Child Welfare Research Station at Iowa City, Iowa, called attention to the occurrence of snuffles and labored breathing in young rats on diets deficient in vitamin A. In a colony of between 400 and 500 animals those on the low vitamin A diets were the only ones that ever manifested such symptoms, and if, after they appeared, change to an adequate supply of the vitamin was made in time, "the appetite improved, the snuffles disappeared and the animals gained in weight." Even before there was any evidence of physical breakdown, while the animals were still gaining in weight, and there were no signs of nasal inflammation, there was found on autopsy marked congestion of the nasal passages and pus in the middle ear and at the base of the tongue.

If the deprivation of vitamin A is postponed until young rats are two months old, instead of being instituted at the age of one month, they are less susceptible to xerophthalmia, but more of them show lung infections. Sherman has emphasized the tendency to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women. Animals whose diet has been relatively poor in vitamin A actually have less of it in their lungs than their better fed litter

[1] Blackfan, K. D., and Wolbach, S. B. "Vitamin A Deficiency in Infants, Clinical and Pathologic Study." *Journal of Pediatrics*, Vol. 3, page 679 (1933).

mates. Even quite moderate differences in the amount of the vitamin in the food may result in distinct differences in the storage in the lungs.

It must also be remembered in this connection that infection tends to interfere with utilization of the vitamin and to cause depletion of body reserves, and also that organisms usually harmless may become quite harmful if the subject has already a low resistance to infection.

How these facts relate to such a malady as the common cold is a matter of great interest, since so many days of absence from school or work are caused thereby. Professor Hazel C. Cameron at the University of West Virginia has contributed a two-year study of the incidence and duration of colds among more than 200 college students. These young men and women were not eating diets deficient in vitamin A, for careful records showed a daily consumption which would be regarded as decidedly liberal for normal adults. In addition to their usual diet, part of them received daily one tablespoonful of standard cod liver oil; another part, carotene in oil; a third part, tablets containing a cod liver oil concentrate; and a fourth part, tablets of plain milk sugar with no vitamin A whatsoever. With the exception of those taking the cod liver oil no one knew whether he was getting vitamin A or not. The number of colds and their duration were compared for all students getting over 7,000 international units of vitamin A (or 5,000 Sherman-Munsell units) daily with the records of those receiving less than this amount. The former averaged 2.4 colds per person of 17.7 days' duration as against 2.8 colds per person of 22.6 days' duration. A similar study, including students in the School of Medicine of Western Reserve University, and members of the hospital staff and nursing group, made by Dr. G. S. Shibley and Dr. T. D. Spies included 241 young adults who were divided into three groups, one receiving halibut liver oil, another corn oil with no vitamin A, and a third vitamin D in oil but no vitamin A. No one knew to which group he

belonged. As in the Cameron study there was no difference in susceptibility to colds, the average number being about the same in the three groups, but there was a definite shortening of several days in the duration of the colds in the group taking vitamin A.

These studies, together with the more technical ones on the changes actually taking place in the tissues, make it clear that vitamin A is distinctly a nutrient and not an antiseptic; that its function is to keep the epithelial cells of the mucous membrane in the best possible condition so that the natural defenses of the organism will be preserved. Sherman suggests that at least four times the amount actually required for apparent health may bring a good return in health protection.

The Urinary Tract

When animals are kept for some time on diets low but not entirely lacking in vitamin A, kidney and bladder stones are frequently found. They have not been found in animals on other types of deficient diet. In chicks, however, vitamin A affects the kidneys, interfering with the normal elimination of waste. According to McCarrison [1] there are certain areas of India, particularly in the northwest, which are known as "stone areas" because of the prevalence of kidney stones among the people. It is a "poor man's disease," occurring among those whose chief dietary staple is cereal of some sort, but is most frequent where vegetation is relatively scanty, where grazing for cattle is poor, and where wheat is the chief food crop. McCarrison has produced calculi in rats in 90 days from weaning time on diets low in vitamin A and consisting chiefly of wheat. The addition of milk at the rate of two thirds of an ounce per rat per day, or of butter or cod liver oil completely prevented the disease, but vegetable oils which lack vitamin A were ineffective. McCarrison believes that there is in addition

[1] McCarrison, R. "A Lecture on the Causation of Stone in India." *British Medical Journal*, No. 1, page 1009 (1931).

to the lack of vitamin A something in the diet of whole wheat which predisposes to stone formation. Although rice eating people or those using white flour are not free from the disease, there seem to be fewer cases among them. McCarrison points out that urinary excretion is more copious on a diet rich in vitamin A, and that this may help to flush out the kidneys and reduce the tendency for phosphates to accumulate.

Even if kidney stones are not a common result of dietary deficiency among the people of America, who are on the whole so much better nourished than the masses of India, there seems to be every reason to believe that many kidney disturbances of middle life and old age have their origin in subacute infections, repeated perhaps many times before any obvious pathological condition develops. It is certainly the part of wisdom to keep such valuable organs in the best possible condition through a regular and liberal vitamin A intake throughout adult life as well as during the period of growth.

The Alimentary Tract

Since it has been fully established that the mucous membrane is very quickly affected by shortage of vitamin A, changes in the alimentary tract are as likely to occur as in the respiratory or genito-urinary tracts. In rats sufficiently depleted to begin to lose weight, diarrhea and other signs of digestive disturbance have often been observed, and in monkeys these are sometimes so severe as to cause death before any signs of xerophthalmia appear. An interesting experiment to test the efficiency of the mucous membrane in guarding against the invasion of the body by bacteria has shown that organisms will not pass through nearly so readily when the body is well protected by vitamin A. The normal controls and the depleted animals were each given the same dosage of the bacteria producing mouse typhoid by means of a stomach tube. At various intervals of time they were killed and the kidneys, spleens, livers, and lungs

examined to see how many of the microörganisms had been able to migrate through the intestinal wall in order to reach these organs. The result of examining them at the end of a nine-hour period is shown below.

Per Cent of Rats Showing Invasion of Bacteria Nine Hours after Administration by Stomach Tube

Organ Examined	Normal Controls Per Cent	Vitamin A-Deficient Rats Per Cent
Kidney	33	80
Spleen	16	66
Liver	38	93
Lung	38	86

A study of the tissue changes has recently been made by Dr. Marion B. Richards [1] of the Rowett Research Institute, Aberdeen, Scotland, who emphasizes the very short time required for pathological symptoms to develop in rats deprived of vitamin A. Here, too, roughened surfaces, clogged ducts, and lack of the normal moistening by secretions lead to inflammation of the whole intestinal tract and to marked alterations in the stomach lining, with pittings, hemorrhages, and in many instances, actual ulceration.

The relation of all this to the human situation remains to be investigated. One of the physicians at the Peiping Union Medical College has described a case in which gastric secretion became greatly diminished but the administration of cod liver oil restored it to normal, and Blackfan and Wolbach reported changes in the epithelium of the alimentary tract of the infants studied by them. Such observations tend to strengthen the view that vitamin A is essential to the full functioning of "the first line of defense," the mucous membrane, in the digestive tract.

The Skin

China is proving a most interesting field for the study of vitamin A deficiencies because of the very low vitamin A intake of the poorer people. During the winter and spring

[1] Richards, M. B. "The Rôle of Vitamin A in Nutrition." *British Medical Journal*, No. 1, page 99 (1935).

of 1928, Dr. C. N. Frazier and Dr. C. K. Hu [1] of the Peiping Union Medical College observed fifteen cases of vitamin A deficiency among young Chinese soldiers garrisoned in villages about Peiping, all of whom had xerophthalmia, and also a peculiar skin disturbance. Their diets consisted chiefly of rice, maize, millet, white cabbage, and salted vegetables. Meat, eggs, and green vegetables were never eaten oftener than once a month and by some of them not at all.

The skin was dry and rough, and at the sites of the hair follicles a pimply eruption occurred, spreading over the upper and lower extremities, shoulders, abdomen, chest, and back. There was a typical clogging of the sebaceous glands, so that a dry, firm papule containing a plug of hardened epithelial cells projected above the surface of the skin like a horny spine. Inflammation developed, due to the irritation, and sometimes small ulcers formed. The skin of the face was also dry and covered with acne-like pimples, which were large and conspicuous. When the patients were put on a well balanced diet and given three tablespoonfuls of cod liver oil daily, the skin became moist, as the sweat glands began to function again, the papules lost their horny cores and in the course of 4 to 6 weeks the pits so formed gradually shrank and disappeared.

An almost identical report was made by Dr. L. J. A. Loewenthal,[2] Medical Officer of the Mulago Hospital, Kampala, East Africa, who found that out of 81 prisoners with night blindness or xerophthalmia, 74 had cutaneous eruptions as described above. Upon treatment with three tablespoonfuls of cod liver oil daily for 9 weeks, with no other change in the diet, 98 per cent of the cases cleared up. Additional evidence that vitamin A was the curative factor was furnished by two patients who were given an extract containing vitamin A only and these, too, were cured within the same period.

[1] Frazier, C. N., and Hu, C. K. "Cutaneous Lesions Associated with Vitamin A Deficiency in Man." *Archives of Internal Medicine*, Vol. 48, page 507 (1931).

[2] Loewenthal, L. J. A. "A New Cutaneous Manifestation in the Syndrome of Vitamin A Deficiency." *Archives of Dermatology and Syphilology*, Vol. 28, page 700 (1933).

Similar observations of these characteristic changes in the epithelial cells of the skin have been made by a number of other investigators. Frazier and Hu found them more frequent in young adults than in those under fifteen years of age, but indications of the same tendency were reported by Helen Mackay in a study of 118 London babies from poor homes. Half of the children were kept on their usual diet of dried milk with one teaspoonful of orange juice daily, while the other half were given additional vitamin A. The vitamin A furnished by the milk and orange juice was sufficient for the control group to grow at practically the same rate as the group whose diet was enriched with vitamin A, and the only outstanding difference was in the condition of the skin. Twice as many babies developed local irritation with an infection by local organisms of low virulence in the group with the lower vitamin A intake, so that Mackay concluded that skin disturbance might be one of the earliest signs of vitamin A deficiency.

In Ceylon, where the diet of the poor is exceedingly low in vitamin A, the children are not only afflicted with xerophthalmia and night blindness, but also with an inflamed and coarsened condition of the skin known as "toad-skin," which clears up on administration of cod liver oil.

Dryness and roughness of the hair is an early symptom of vitamin A deficiency in the rat, and is also noticed in human beings. With administration of vitamin A improvement is marked in a very short time, the hair becoming soft and glossy again.

The Teeth

There is a growing conviction that by improving the diet of children after birth and of their mothers during pregnancy, the present discouraging situation of 95 per cent of our school children having seriously defective teeth can be radically changed. At present, the evidence is more conclusive for a very good diet as a whole rather than for any single factor. Nevertheless the outstanding researches

of Dr. S. B. Wolbach of Harvard University and Dr. P. G. Howe of the Forsyth Dental Infirmary in Boston have made it clear that vitamin A exercises a very definite control over tooth development.[1] When rats are placed on a diet lacking vitamin A, their teeth become chalky, white, and brittle, owing to the loss of the enamel with its orange colored pigment and the exposure of the dentine. The development of the enamel is controlled by the enamel organ, a complex structure of epithelial origin, which begins to degenerate as soon as vitamin A is withheld. The formation and maintenance of the dentine depends upon the odontoblasts, a single layer of very active cells arranged in an orderly row between the pulp and the dentine, and sending filaments into both. The changes in the enamel organ affect the odontoblasts first on the side opposite to the enamel organ and the dentine on that side becomes thin and defective while increasing on the other side, so that the tooth in cross section becomes much distorted. Eventually all the odontoblasts shrink and shrivel and the dentine as well as the enamel becomes strikingly defective.[2]

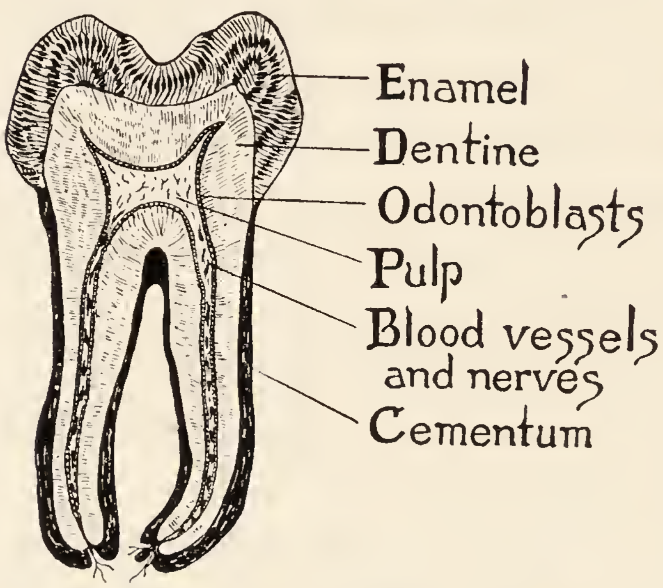


FIG. 62.—A diagram showing in cross section the relationship of parts in a tooth.

The health of the teeth is not only affected by these controlling organs within the structure of the tooth itself but also by the soft tissues in which they are imbedded, upon which proper position in the jaw and freedom from bacterial invasion of the gums to a very considerable degree depend. In England Lady Mellanby has studied for many

[1] Wolbach, S. B., and Howe, P. G. "The Incisor Teeth of Rats and Guinea Pigs in Vitamin A Deficiency and Repair." *American Journal of Pathology*, Vol. 9, page 275 (1933).

[2] For a detailed description of the structure and development of the teeth consult Mellanby, May. *Diet and the Teeth, Part III. The Effect of Diet on Dental Structure and Disease in Man.* Medical Research Council, Special Report Series No. 191. His Majesty's Stationery Office, London (1934); and Bodecker, C. F. "Nutrition of the Dental Tissues." *American Journal of Diseases of Children*, Vol. 43, page 416 (1932).

years the effect of vitamin A on the teeth of rats and puppies, and her conclusion with regard to vitamin A is as follows: "It is of fundamental importance to include vitamins A and D in the diet during the early developmental period if the periodontal tissues are to resist disease. A large supply of these vitamins during a later period even from the fifth month onwards, does not compensate for a deficiency during the earlier period. Vitamin A in very large doses may prevent the spread of the pathological condition." [1]

Since the enamel organ and the mucous membrane of the surrounding soft tissue are of epithelial origin these studies of the teeth add one more link to the chain of evidence that vitamin A is essential to the health of epithelial tissue everywhere in the body and the wide distribution of epithelial cells explains the great variety of symptoms observed when vitamin A is lacking.

The Nervous System

When animals have been completely deprived of vitamin A at weaning time, they grow until their body reserves are exhausted and then decline rapidly, dying in a short time, as shown in Fig. 57. But if they are given small amounts of vitamin A after depletion they will live for 8 or 10 weeks, but succumb to incoördination, muscular weakness, and paralysis. Early observers of these symptoms attributed them to other causes, but in 1928 Professor J. S. Hughes and his associates at the Kansas Agricultural Experiment Station found that pigs placed at weaning on a diet deficient in vitamin A developed unsteadiness of gait in 6 to 7 months, and could be cured by addition of cod liver oil to their diet. Examination of the nervous system showed some very marked degenerative changes. Again, in 1932, Elvehjem and Neu, at the University of Wisconsin, depriving day-old chicks of vitamin A, found that one of the most striking results was the development of a staggering gait and finally

[1] Mellanby, M. *Diet and the Teeth*, Part II, page 31. Medical Research Council. Special Report Series No. 153. His Majesty's Stationery Office, London (1930).

paralysis as shown in Fig. 54. This same year, Dr. W. E. Krauss and his associates at the Ohio Agricultural Experiment Station, trying to maintain rats on very low vitamin A levels found that after 40 to 50 days over half of the animals showed paralysis in their hind legs, and great weakness and wasting of the muscles. This led to a detailed study of

Fig. 63.—These two rats are the same age. The upper one had an adequate diet, the lower one a diet lacking vitamin A. The animals are trying to stand on a slanting wire screen. The upper one has no difficulty in spreading its hind legs to maintain its position but the lower one has paralysis in the hind leg exposed and is unable to use it.

the nervous system which showed that the disturbance was due to degenerative changes in the spinal cord and in the medullary sheaths of the sciatic and vagus nerves. The first outward manifestation was a peculiar weaving, unsteady gait in the hind limbs, an increasing flabbiness of the muscles, and finally paralysis. In order to find out whether there

was a true vitamin A deficiency, tests were made on the epithelial cells from the mucous membrane of the vagina and these always showed typical keratinization.[1] This was necessary because the animals do not recover upon vitamin A administration when the nerve degeneration has become severe.

While these studies were going on in Ohio, the same symptoms in rats were encountered in the School of Medicine of Yale University and in 1933 Dr. H. M. Zimmerman reported a very detailed study of the nervous systems of nine rats. It was found that while the administration of carotene late in the course of the dietary deficiency would not prevent a fatal outcome, it would restore the animals to good health but would not restore the use of the paralyzed parts.[2] A typical case of paralysis is shown in Fig. 63.

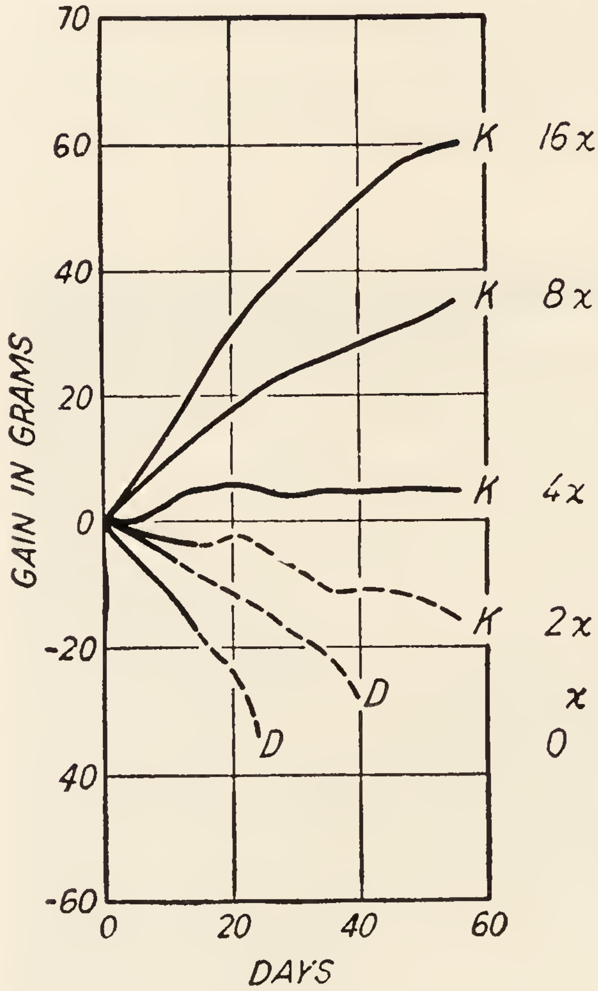
Measurement

When young rats weaned from mothers on an adequate diet at the age of 28 days are put on a diet lacking only vitamin A, they continue to grow for a time. But eventually growth ceases and signs of vitamin A deficiency such as xerophthalmia, rough coat, snuffles, and sneezes appear. Soon a rapid decline leads to death. Growth ceases only when the reserves of vitamin A in the animal's body are practically exhausted. If then as little as one thousandth of a milligram of pure carotene be fed, the animal will begin to grow and the symptoms of vitamin A deficiency will disappear. Instead of pure carotene, a food containing vitamin A may be given, and by graded doses growth can be controlled as shown in Fig. 64. Sherman and Munsell have perfected a technic for the quantitative determination of vitamin A in foods by use of the white rat. A unit of vitamin A according to their technic is that amount of food

[1] Sutton, T. S., Setterfield, H. E., and Krauss, W. E. *Nerve Degeneration Associated with Avitaminosis A in the White Rat.* Ohio Agricultural Experiment Station Bull. 545, (1934).

[2] Zimmerman, H. M., and Cowgill, G. R. "Lesions of the Nervous System in Vitamin Deficiency. IV. The Effect of Carotene in the Treatment of the Nervous Disorder in Rats Fed a Diet Low in Vitamin A." *Journal of Nutrition*, Vol. 11, page 411 (1936).

which when fed daily just suffices to support a gain of three grams per week in a standard test animal on a standard vitamin A-deficient diet during an experimental feeding period of from four to eight weeks. By this method the vitamin values of a great many foods have been studied and the shares per ounce, pound, and 100 calorie portion will be found in Table I of the Appendix. In 1931 a committee of the League of Nations met in London to consider international vitamin units, and the one proposed for vitamin A was the amount equivalent to 0.001 mg. of a carotene preparation distributed to various laboratories by the Health Organization of the League. Subsequently this was found to be a mixture of alpha and beta carotene and the unit was redefined in terms of pure beta carotene as 0.0006 mg. This unit has been adopted by the United States Pharmacopeia. To express the vitamin A values in this book in terms of this international unit multiply by 1.4.



(*Courtesy of the* Journal of Biological Chemistry)

Fig. 64.—Average gains of rats fed different amounts of vitamin A after having been depleted of their bodily store. Figures opposite end of each curve represent relative amounts of vitamin A fed. A broken line is used to indicate that one or more rats have died. When all animals died before the end of the 8 weeks period (*K*), the curve is terminated at a point representing the average weight and age at death (*D*).

Sources

Vitamin A was first discovered in animal fats, butter, egg yolk, and cod liver oil, and was not found in any of the oils of plant origin examined at that time. But very shortly it was found in the green leaves of alfalfa, cabbage, spinach, and young clover, and eventually Drummond showed that

the cod and other fishes derive their vitamin A from small marine animals which in turn get it from various minute marine plants, algæ, and the like. Thus the dependence of the animal upon the plant for vitamin A was established. Furthermore, it was shown that when seeds are sprouted in the absence of light, little if any vitamin A is produced, but as soon as the sprouts come to the light and their tips begin to turn green, vitamin A is rapidly formed. Leaves which do not turn green, such as the inner leaves of lettuce and cabbage, are not nearly so rich in the vitamin as the green parts. In general, the thinner and greener a leaf is, the better source it is likely to be, any typical green leaf being weight for weight in its fresh raw state more than the equivalent of butter or egg yolk. Next to green leaves, the growing stems or shoots of plants, and the germs of seeds are with few exceptions the most important vegetable sources. Green string beans, asparagus, and green peas are about as rich as the average head of lettuce.

The storage parts of plants, as thickened roots or tubers, and the endosperm of seeds, are relatively poor in vitamin A, but there is much variation among individual plants; yellow maize is richer than white corn; sweet potatoes, than white ones; and carrots are conspicuous among "underground" vegetables for a vitamin content higher than any other common vegetable except green leaves. Of fruits investigated, the apricot is the richest; the banana is about as good as brussels sprouts; the yellow peach is about twice as rich as the average lettuce head; orange juice has about one eighth as much as tomato juice.

Animals may get their vitamin A from plants or from other animals. The grass-eating cow is a great conserver of this substance for human consumption. Milk stands preëminent among food materials as a source of vitamin A, which is not all removed with the butter fat, skim milk containing an appreciable amount. The value of the milk and of the butter made from it is influenced by the diet of the cow, milk produced in the summer when the animal is furnished

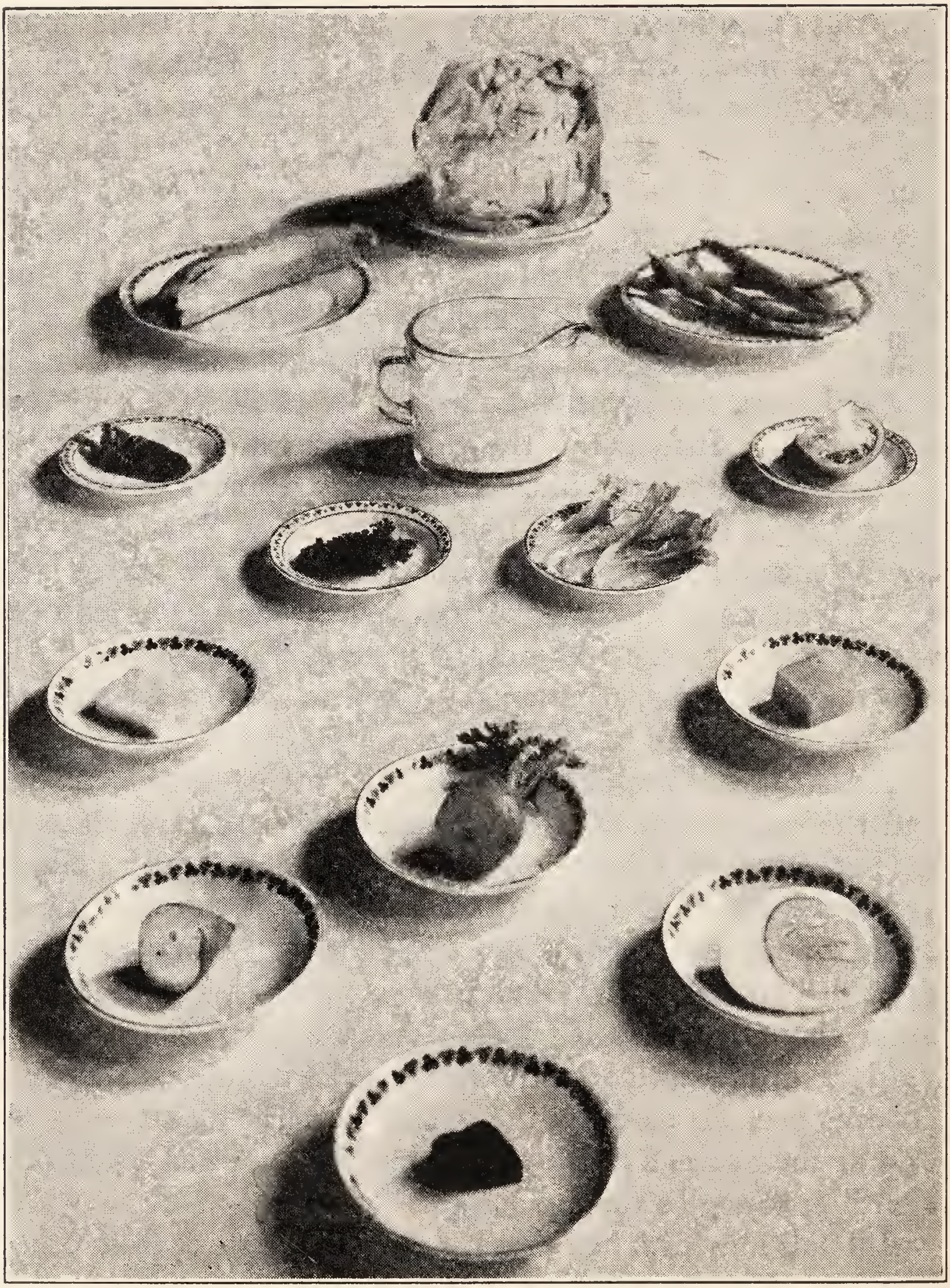


Fig. 65.—Foods Yielding about 250 Units of Vitamin A.

	Grams		Grams		Grams		Grams
Lettuce, head	200	Milk..........	120	Butter.........	7	Potato, sweet	10
Banana.....	162	Tomato........	32	Cheese, American	10	Egg yolk....	7
Beans, string	27	Kale..........	1	Carrot.........	10	Liver.......	3
Spinach.....	2	Lettuce, Romaine	2				

a plentiful supply of green food being richer than the winter product; but in practice this difference is much less than is generally supposed, because most milk comes from cows which get good hay or ensilage in winter.

The storage of vitamin A in the tissues of animals has already been referred to. Muscle contains very little under the most favorable feeding; glandular organs contain more, the liver being richest of all. Egg yolk resembles butter in its high content of A. Halibut liver oil has the highest concentration of any known source, being from 60 to 100 times as rich as cod liver oil. A cod liver oil concentrate 1,000 times as rich as the original oil has been prepared in the laboratory.

Vitamin A in animal fats loses its potency gradually on exposure to the air, and more rapidly when thoroughly aërated, especially if the temperature is raised. As it exists in plant tissues it is not so easily oxidized and withstands drying and ordinary cooking temperatures without marked loss.

Requirement

The necessity for a liberal supply of vitamin A in the human diet has been established beyond doubt. The next important question is how much is required for the best protection? We have already seen that requirements are high in periods of rapid growth, in pregnancy, and lactation. Also in illness special diets should be so planned as not to deprive the patient of any vitamin.

In normal infants good protection seems to be afforded by the vitamin A furnished by a quart of whole milk. In Dr. A. F. Hess's service at the Home for Hebrew Infants in New York City [1] it was found that no better protection was secured from respiratory infections by means of further increases in the vitamin A intake when the children were already getting from 600 to 1,000 cc. of milk and about 10

[1] Barenberg, L. H., and Lewis, J. M. "Relationship of Vitamin A to Respiratory Infections in Infants." *Journal of the American Medical Association*, Vol. 98, page 199 (1932).

grams of butter daily. A quart of milk (935 cc.) yields about 2,000 units of vitamin A and 10 grams of butter at least 300 units, making a daily intake for these infants of about 2,300 units, or approximately 200 units per 100 calories.

In the diets of nursery school children Rose, Robb, and Borgeson found the daily supply of vitamin A at school about as follows:

Food	Measure	Units of Vitamin A
Milk	16 oz.	1,000
Cod liver oil	1 tsp.	2,000
Butter	1 tsp.	100
Egg yolk	1 yolk	825
One vegetable rich in vitamin A	2 tbsp. carrots	1,000
		4,925

If the home diet includes another pint of milk, another teaspoonful of butter, and one vegetable rich in vitamin A daily, the diet of a nursery school child will contain from 6,000 to 7,000 units of vitamin A per day, or at least 300 units per 100 calories.

In dental studies made by the School of Oral and Dental Surgery of Columbia University reported by McBeath the diet of certain groups of children 5 to 17 years old was planned to insure the daily consumption of the following foods which are excellent sources of vitamin A, viz., a quart of milk, one or two eggs, two ounces of butter, and three teaspoonfuls of cod liver oil. The yield of vitamin A in this diet in three different institutions ranged from about 13,500 to over 16,000 units per child per day, while the regular (and excellent) institutional diets yielded from 5,000 to 7,700 units per child per day or from 250 to 300 units per 100 calories.

There was no evidence that the incidence of caries was altered by the greatly increased intake of vitamin A by the experimental groups. The children on the regular institutional diets were reported to be normal and growing well, hence these studies furnish further evidence that 300 units per 100 calories may be considered liberal for a growing child. Just how much less may be reasonably safe will require in-

vestigation. Rose and Gray, in a long study of an institution in which a number of children had remained from early childhood until adolescence found that most of the children had made fairly good but not optimum growth both in height and weight. Although the diet was an exceedingly economical one with very few eggs and little butter, it included a quart of milk daily for each child, and most of the vitamin A came from this. The daily intake of the vitamin averaged about 2,500 units per child per day or 130 units per 100 calories. In this institution the minimum vitamin A requirement for growth was apparently covered, although in the light of present knowledge of the advantages of good reserves of vitamin A, it seems a small allowance. The dietary has been recently improved by the daily use of at least a teaspoonful of cod liver oil per child.

These studies seem to indicate that while a child may make fairly good growth on a diet in which a quart of milk a day is the chief source of vitamin A, better provision for development and protection against infection will be afforded if the vitamin A intake is increased to at least twice the units in a quart of milk, making a minimum allowance of about 200 units per 100 calories.

The requirement of the adult is less per unit of weight because of the cessation of growth. It seems fairly safe to assume, from a study of dietaries upon which good health has been maintained over long periods, that an adult man will be protected by the vitamin A from one pint of milk plus one ounce of butter, which would mean about 2,000 units daily. But it would also seem wise to allow at least as great a margin of safety as in case of calcium or phosphorus, and hence a good tentative dietary standard for an average man would seem to be about 3,000 units per day. For a man requiring 3,000 calories this would mean 100 units for every 100 calories. Eggs, vegetables, and additional milk and butter will easily increase the total amount in the diets of the well-to-do, but for those of very limited incomes the simplest way to insure an unquestionably satisfactory supply

is to supplement the diet daily with a small portion of cod liver oil or of halibut liver oil, or of some reliable concentrate whose vitamin A value is known. Since the capacity for storage of vitamin A is very great, still more liberal amounts may be a good health investment. Sherman says: "It seems wise for those who can afford it to invest rather liberally at all ages in food rich in vitamin A, knowing that in this case the body will store the surplus to an extent and with an efficiency which is not to be expected in the case of most other nutrients."

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CHAPTER XI

VITAMIN B (B_1) AS A REGULATOR OF BODY PROCESSES

Discovery

We must now turn our attention to another line along which knowledge of the vitamins has developed. For centuries there has been widespread in the Orient a nerve disease called beriberi, said to have been known to the Chinese as early as 2600 B. C. The Malay States, Siam, Korea, Japan, and the Philippine Islands have been greatly afflicted by it, and it is more or less prevalent in India and in Africa. That it is not confined to tropical regions is shown by its occurrence in recent times in Newfoundland, Labrador, and Norway. In 1872 there entered the Japanese navy a young medical officer named Takaki, who noticed the great havoc wrought by beriberi, and determined to find the cause and a remedy if it were possible. For the sake of more knowledge he went in 1875 to England and entered St. Thomas's Hospital Medical School, where he remained five years. Upon his return he was made Director of the Tokyo Naval Hospital, and began to study everything that might throw any light on the cause of this scourge. He finally came to the conclusion that the disease was of dietary origin, and having been made Director-General of the Medical Department of the Navy, he succeeded in obtaining permission from the Japanese Admiralty to make a number of experiments in the service "upon a scale of great magnitude." [1]

On December 19, 1882, the "Riujo," a training ship bearing 276 men, sailed from Yeddo Bay to New Zealand, South America, and Hawaii, and then back to Japan, a voyage

[1] Takaki, K. "The Preservation of Health amongst the Personnel of the Japanese Navy and Army." *Lancet*, Vol. I, page 1369 (1906).

lasting 272 days. There were 169 cases of beriberi and 25 deaths before reaching Honolulu. Then Takaki sent the "Tsukaba," another training ship, with a similar crew over the same course, but with a better ration as shown by the following table:

	Diet on the "Riujo"	Diet on the "Tsukaba"
Food	*Weight Ounces*	*Weight Ounces*
Rice	27.78	32.16
Vegetables	9.56	12.41
Fish	4.85	6.56
Meat	2.18	8.02
Other food not specified	—	Milk and tea added
Total weight of ration	50.37	78.38

The "Tsukaba" was gone 287 days, but only 14 men had beriberi, and these did not eat their full allowance of the new ration. As a result of this experiment, in 1885 Takaki secured the adoption of a new dietary for the entire Japanese navy, in which the total food was further increased, the rice decreased, wheat and bread added, the vegetables increased, and the milk allowance made $1\frac{1}{4}$ pints daily.

A few years later, in the Dutch East Indies, Dr. C. Eijkman, director of the hygienic laboratory at Batavia, Java, noted that certain fowls manifested symptoms curiously like beriberi, and began an investigation of the cause. In 1897 he reported that the disease of the fowls (polyneuritis) was the same as beriberi in man, and was due to the lack of some substance essential to normal nutrition not present in polished rice but obtainable from the rice polishings. Eijkman induced the government to order an examination into the influence of rice feeding on human beriberi in the prisons of Java, by which it was shown that only one in 10,000 living on unpolished rice acquired the disease, while 3,900 in 10,000 living on polished rice developed it. The work of Eijkman was extended by Grijns, who showed that the antineuritic substance which Eijkman had found in the outer layers and embryo of the rice kernel also oc-

curred in certain beans (*Phaseolus radiatus*). Their efficacy was put to the test by the sanitary inspector of Java, who for nine months gave part of the inmates of a certain lunatic asylum white rice only and another group rice plus about 5 ounces of the beans daily, and found that no one who ate the beans had beriberi, while over one third of those who did not eat them developed the disease.

During the World War the British troops in the Dardanelles and Mesopotamia, on their diet of white bread suffered severely, but the Indian troops on whole grain flour and chick peas did not have the disease. During the later days of the siege of Kut-el-Amara, the British troops were free from beriberi because they ate the Indian whole grain flour after their own white flour had given out.

Such experiences greatly stimulated effort to discover the nature of this antineuritic substance. Several independent investigators within less than a year (December, 1911–July, 1912) succeeded almost simultaneously in separating from rice bran and from yeast a substance which would cure the disease when induced in pigeons by feeding polished rice. Of these, Casimir Funk was the first to announce publicly that he had been able to cure, in a few hours, pigeons paralyzed by polyneuritis, by a few milligrams of the crystals which he had prepared from the rice bran (December, 1911). He suggested for this substance the name *beriberi vitamine.*

While Eijkman was investigating the antineuritic properties of rice polishings, Hopkins in England was seeking the reason why a very small portion of milk added to a diet of purified proteins, fats, carbohydrates, and mineral salts made the difference between nutritional success and disaster. He was able to show that in milk and certain vegetables there was something soluble in water and also in alcohol which, when added to the ration of purified foodstuffs, enabled young rats to grow.

Also, in New Haven, Osborne and Mendel were finding repeated instances of the superiority of their "protein-free milk" over a mixture of pure lactose plus pure mineral salts

added to their basal diet, which led them to realize that they were dealing with some specific water-soluble growth promoting substance.

This was also just about the time that Hart, Humphrey, Steenbock, and McCollum published the first report of their investigations in feeding cattle on rations from a single plant source, and began the search for an explanation of the differences in the nutritive value of the ration prepared from the corn plant and that from the wheat plant. McCollum and Davis found that the wheat kernel, supplemented with purified casein, a mixture of mineral salts and butter fat, provided a diet satisfactory for the growth of the young to maturity, the maintenance of the adult, and the production of vigorous offspring. But no such success attended the application of the same procedure to polished rice. The animals failed to grow and developed polyneuritis. They then tried replacing part of the rice by milk sugar, with the result that the animals began to grow as soon as it constituted 5 per cent of the ration. If, however, they used highly purified milk sugar, there was no growth. Thinking that something must have been left behind in the water from which the milk sugar had crystallized out, they evaporated this on the food mixture and the ration so reinforced was able to sustain growth. In 1915 this new growth promoting food factor was called by McCollum "water-soluble B." He found that pigeons could be cured of polyneuritis by adding to polished rice the same preparation which had been found to induce growth in rats, and concluded that a single substance possessed both antineuritic and growth promoting properties. It soon came to be known as vitamin B. But as the quantitative study of its presence in foods was promptly pursued in many laboratories, various unaccountable irregularities in the results suggested that there must be more than one vitamin. Thus yeast when heated under pressure (autoclaved) lost its power to cure polyneuritis in a pigeon yet it could still stimulate growth in a rat. It took a number of years for the full significance of such conflicting results to

be reconciled, but by 1928 it was finally established beyond doubt that what had been thought a single vitamin was in reality a mixture containing an antineuritic substance, thenceforth called vitamin B, and another growth promoting factor, which received the name of vitamin G. This vitamin will be discussed in Chapter XIV.

The Crystallization and Chemical Identification of Vitamin B

Funk in 1911 prepared a few crystals of what he called the "beriberi vitamine" but could not find a way to get sufficient material for further study. It was not until 1926, in the laboratory in Java where Eijkman had made his pioneer studies, that pure crystals, prepared by Dr. B. C. P. Jansen and Dr. W. F. Donath, were used to cure human beriberi. Within a very few years workers in Japan, Germany, and England were also able to obtain crystals which by all biological tests seemed to be identical.

The next step was their chemical analysis, and here, too, there was soon agreement that the vitamin contained carbon, hydrogen, oxygen, nitrogen, and sulfur, but results in computing the proportions of each element differed slightly. Progress was difficult because of the small amount of material available for analysis. Among those actively seeking to solve the problem of chemical structure was Mr. R. R. Williams, Chemical Director of the Bell Telephone Laboratories, who made his avocation research upon vitamin B. In the Philippines he had seen beriberi at first hand and returning to this country, labored for nearly 24 years in research which finally led to the development of a method by which he could extract as much as 5 grams of pure crystals from a ton of rice polishings. With sufficient material and able assistance from the Carnegie Institution of Washington, which supplied funds; from the Laboratory of Physiological Chemistry at Teachers College, Columbia University, where much of the work was done; from Professor H. T. Clarke, head of the Department of Biochemistry of the College of Physicians and Surgeons of Columbia University; and from other able

assistants, the problem of chemical structure was attacked with fresh zeal. A misfortune of earlier years was turned to good account, for sulfur dioxide which destroyed the vitamin where it was used as a preservative for rice polish extracts, proved a tool for neatly splitting the molecule into two pieces. One of the pieces contained the sulfur, and this was found to be held in a chemical structure not hitherto found in nature, so that Williams remarks, "It is not difficult to imagine that its discovery may ultimately prove more important in biochemistry than the structure of the vitamin itself." [1] Only the development of new technics in chemistry

FIG. 66.—Crystals of Vitamin B Hydrochloride.

made possible the many tests which were necessary for the full identification of both parts of the molecule and of the way in which they are so lightly held together that many earlier investigators failed to even extract the vitamin because its physiological activity was destroyed in the process through its division into these two parts.[2]

[1] Williams, R. R. "The Vitamin B Adventure." *American Journal of Public Health,* Vol. 25, page 481 (1935).

[2] The analysis showed the numerical formula of vitamin B_1 hydrochloride to be

The next objective was to find a way to synthesize the vitamin. This would not only afford final proof that the chemical analysis was right, but would open the way to commercial manufacture of the vitamin, and afford material for further study of the functions of the vitamin in nutrition, which can be carried on more effectively when a plentiful supply of pure substance is available. Nearly two years more were spent in this phase of the investigation and in 1936 the building of the molecule in the laboratory, step by step, was finally accomplished.[1]

In order to distinguish vitamin B, whose chemical identity has thus finally been established, from other vitamins now known to be present in the extract which McCollum originally called "water-soluble B," or what has been more recently designated the "vitamin-B complex," it has been recommended that the term vitamin B_1 be used to avoid confusion. In this book the part of the complex meant by vitamin B will always be B_1.

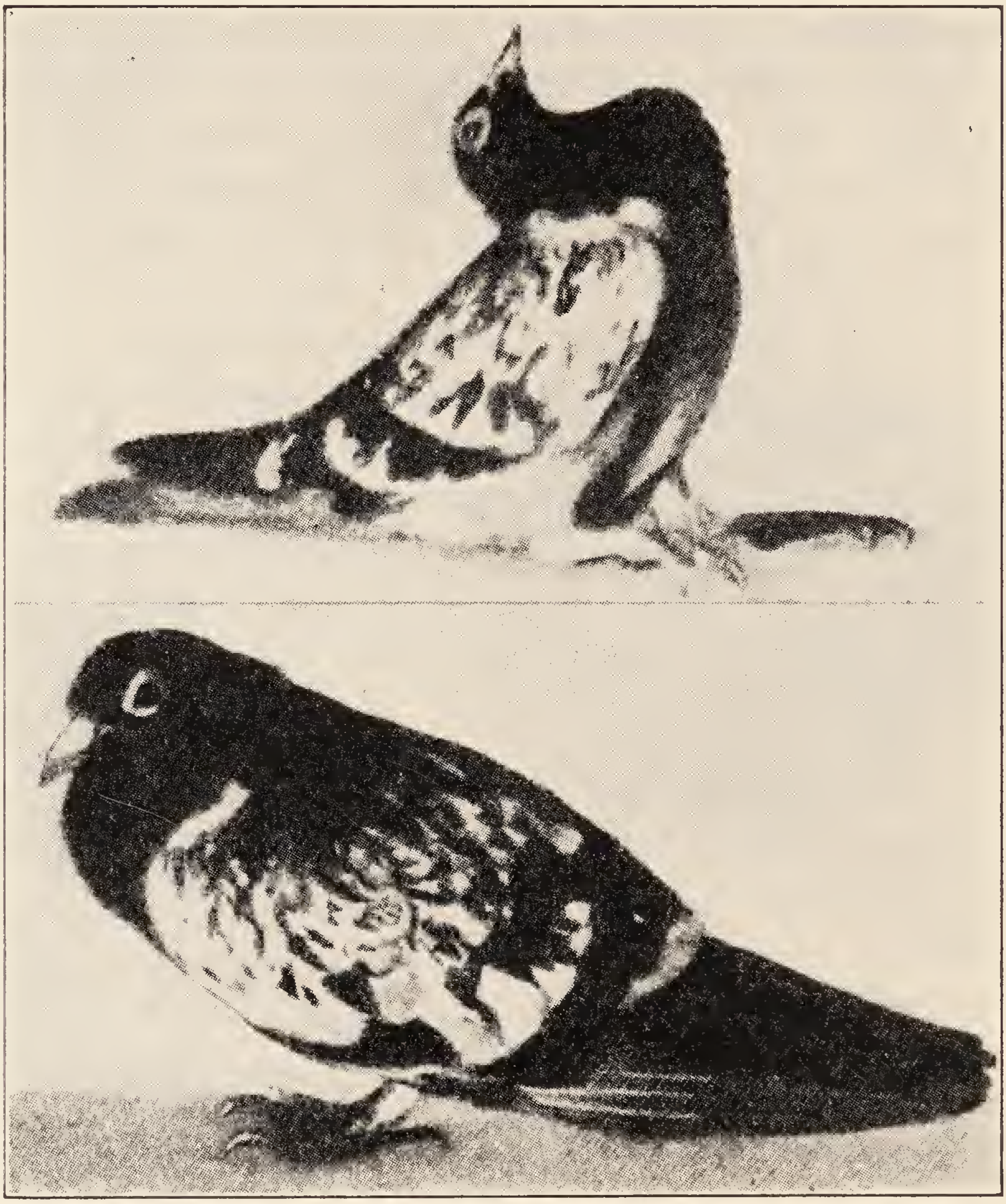
Prevention and Cure of Beriberi and Polyneuritis

Beriberi is a disease characterized by changes in the nervous system which have far reaching effects throughout the whole body. In human beings it has two fairly well defined forms: dry beriberi, in which there is great muscular wasting, loss of sensation in the skin, paralysis beginning in the legs and finally extending to the upper portions of the body; and wet beriberi, in which there is a marked infiltration of fluid into the arms, legs, and finally the trunk, with great enlargement of the heart, so that death from heart failure is common. The disease develops on diets low but not completely lacking in vitamin B. They are usually poor in other respects, so that the uniformity of symptoms observed in laboratory animals does not occur. A great deficiency of vitamin B produces the disease rapidly, but a less severe

$C_{12}H_{18}N_4Cl_2SO$. For the structural formula consult Sherman's *Chemistry of Food and Nutrition*, 5th edition, page 389. The Macmillan Co. (1937).

[1] Williams, R. R., and Cline, J. K. "Synthesis of Vitamin B_1." *Journal of the American Chemical Society*, Vol. 58, page 1504 (1936).

shortage may delay development of acute symptoms for a long time, and slight deficiency gives rise only to subacute symptoms which will be discussed in later pages in connec-



(*Courtesy of Dr. Casimir Funk and the* British Medical Journal)

Fig. 67.—The upper pigeon, raised on a diet lacking vitamin B, shows the typical head retraction of polyneuritic birds. The lower pigeon was raised on the same diet plus rice polishings as source of vitamin B and is normal in every way.

tion with appetite and digestion. Beriberi often follows prolonged fevers, especially malaria. In such a situation bad gastro-intestinal conditions and an increased energy expenditure tend to accentuate the effect of a diet deficient in vitamin B.

In pigeons deprivation of vitamin B results in polyneuritic symptoms in from three to five weeks. Sometimes there is weakness and general paralysis, sometimes there develops

(*Courtesy of Dr. G. R. Cowgill*)

Fig. 68.—The upper figure shows a dog with polyneuritis. The hind legs are paralyzed so the animal cannot stand. The lower figure shows the same dog 18 hours later, after receiving tomato juice. Recovery is almost complete.

the typical head retraction shown in Fig. 67. In dogs there is a tendency for paralysis to manifest itself in the hind legs as shown in Fig. 68.

In young rats a characteristic distortion of the spinal column is one of the first symptoms of the nerve involvement which is always a result of vitamin B deficiency (Fig. 69).

In human beings it has only recently been realized that

deficiency of vitamin B may be responsible for various forms of nerve disturbance. The ordinary American dietary tends to be low in vitamin B and if there is any failure of absorption because of unfavorable conditions in the alimentary tract or because of infection, a real deficiency may exist

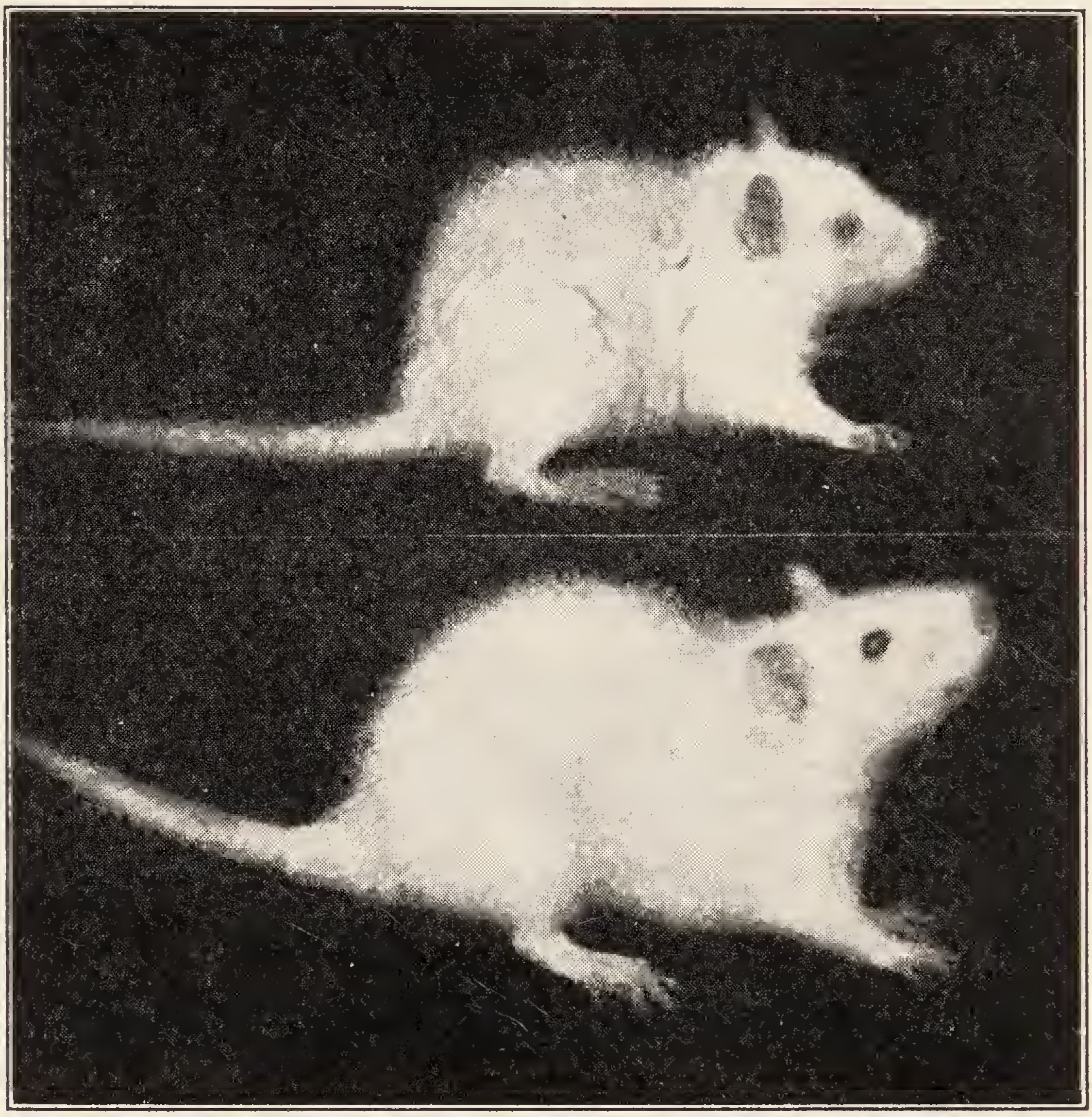


FIG. 69.—These two rats are the same age, 8 weeks. The lower one had an adequate diet, the upper a diet lacking vitamin B, after weaning at the age of 4 weeks.

where it is not suspected. A study of 100 cases of human neuritis by Drs. M. G. Vorhaus and R. R. Williams adds new emphasis as to the value of vitamin B for the well-being of the nervous system. Many of these were of long duration and unresponsive to other forms of treatment, but only 10 per cent failed to improve when given 10 milligrams of pure vitamin B daily, and 44 per cent were entirely cured.[1]

[1] Vorhaus, M. G., and Williams, R. R. "Studies on Crystalline Vitamin B." *Journal of the American Medical Association*, Vol. 105, page 1580 (1935).

The cause of these symptoms in the peripheral nerves was first sought by histological examination of the nerve fibers, but no changes in their structure were found which could account for the severity of the symptoms or the speed with which they could be cured. It is a spectacular effect

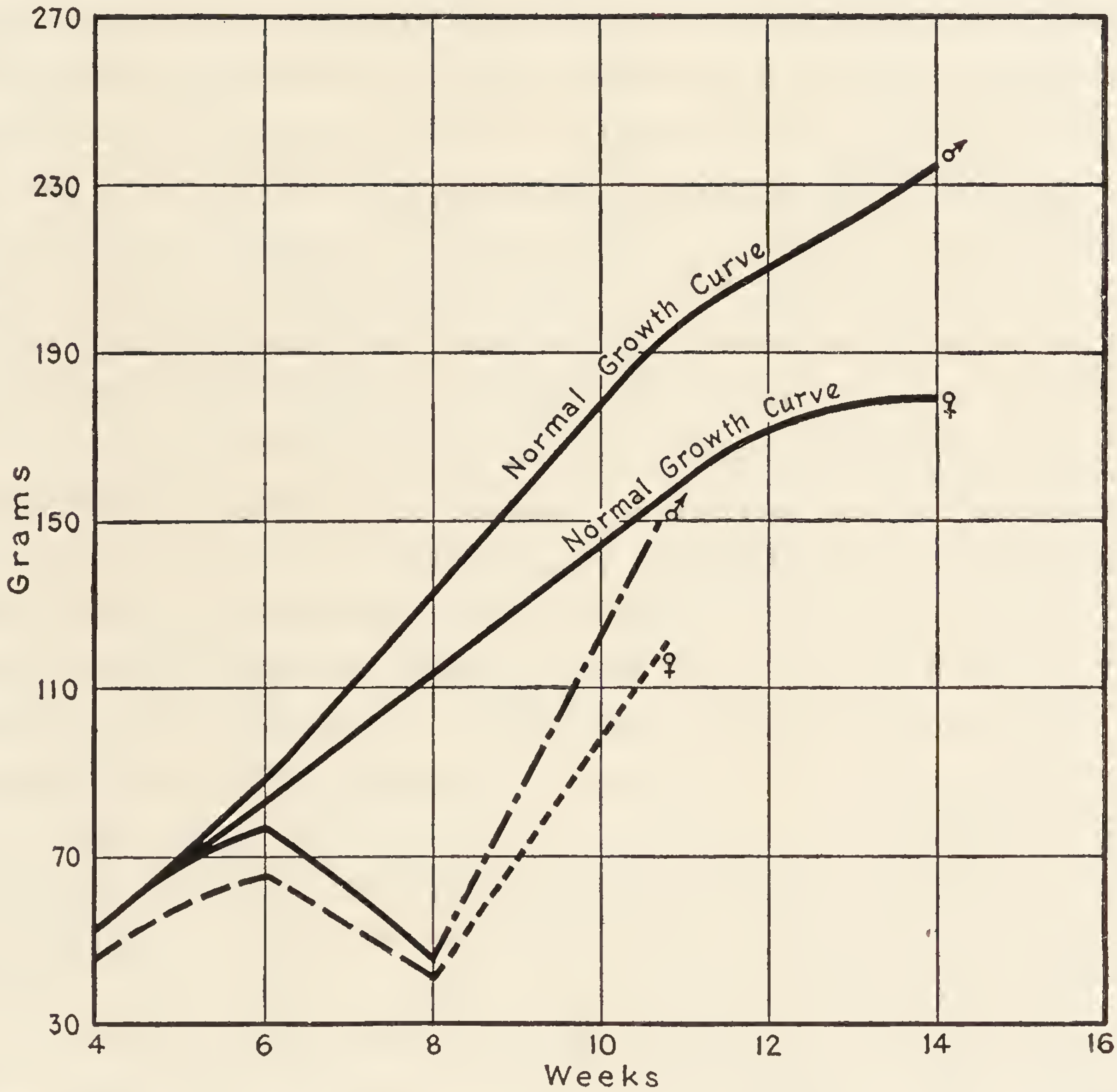


FIG. 70.—Growth curves of rats on a vitamin B free diet compared with those of normal rats of the same age. When vitamin B in the form of wheat germ extract was added to the diet the weight was tripled in less than 3 weeks.

which one observes when a rat, moribund from inanition and polyneuritis, unwilling to eat and unable to swallow, can be revived within two or three hours if given massive doses of vitamin B by mouth with a medicine dropper, and still more dramatic if the vitamin is injected directly into the blood stream, because the recovery may take no more than a quarter or half an hour. It was the successful use of this latter method of curing polyneuritis that aided Williams materially in developing his method of isolating vitamin B

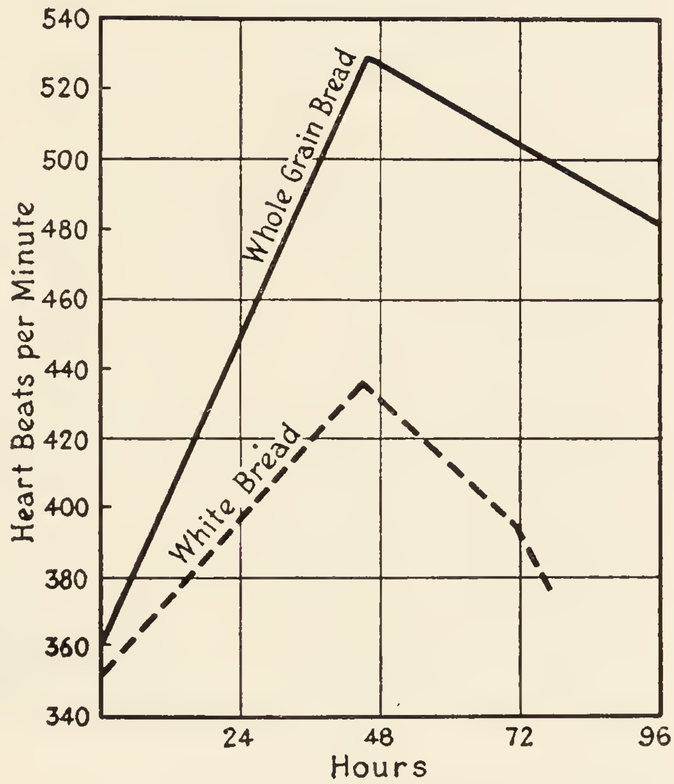
from rice bran, since at each step of the work tests could be made to see whether the vitamin was in a solution or in the material filtered out or had lost its physiological activity.

Such changes are too speedy to involve regeneration of tissue. Hence the solution of the problem had to be sought by study of function. In 1929, Professor R. A. Peters of the University of Oxford started a series of investigations which have yielded the explanation of the origin of polyneuritis. It was found that pigeons dying of polyneuritis have an increased amount of lactic acid peculiarly localized in the lower parts of the brain, and not in the cerebellum. Upon further study, it was discovered that when a portion of tissue from the brain of a polyneuritic pigeon was put into a suitable type of respiration chamber, and supplied with glucose for oxidation, it was unable to oxidize it as fast as the brain tissue from a normal bird, as shown by the rate of oxygen consumption. In the normal brain, as glucose is metabolized lactic acid is formed, but is as quickly changed either back to glucose or by further oxidation to pyruvic acid, which eventually is burned completely to carbon dioxide and water. The accumulation of lactic acid was found to be just one phase of faulty carbohydrate (glucose) metabolism, the real seat of the difficulty being inability to make any further change beyond the pyruvic acid stage. So this, too, tended to accumulate in the brain, poisoning the centers there.

Proof that shortage of vitamin B was responsible was furnished by injecting it under the skull into the part of the brain where the lactic acid had accumulated. In an hour the acute nervous symptoms would disappear and the power of the brain tissue to use oxygen for carbohydrate combustion would be restored. Also the accumulations of lactic and pyruvic acids would disappear. This not only solved the problem of the cause of polyneuritis but also the connection of vitamin B with carbohydrate metabolism. Funk first called attention to the fact that polyneuritis developed more quickly if the animals were given diets very rich in carbohydrate, and Vedder, from his long experience

in the Philippines was convinced, as have been practically all experienced workers in the field, that there was a connection of some sort, although no one had been able to find conclusive evidence.

According to Dr. L. J. Harris of the University of Cambridge, pyruvic acid in the blood is a poison to the muscles of the heart, which slows its beat till that of a polyneuritic rat will be only about half as fast as that of a normal animal. The response is so prompt and so nicely regulated by the amount of vitamin B administered, that Harris and his associates have used it as a test for the vitamin B content of foods. Rats deprived of the vitamin are tested from day to day after they begin to decline in weight, by making tracings of the heartbeat, which is measured electrically, being too fast to count. When the rate falls from the normal level of about 500 beats per minute to about 350, a portion of the food to be tested is given, and after 24 hours another record of the heart rate is made. If the rate has increased, further records are made twice daily till the rate has fallen to the same level as at the beginning. The difference in effect of a gram of whole grain bread, rich in vitamin B, and one of white bread which has only a very small amount derived from the yeast, is shown in Fig. 71.



(*After Birch and Harris*)

FIG. 71.—The effect of feeding a single portion of whole grain bread, rich in vitamin B, on the rate of the heart beat of a rat after the rate had been retarded by deprivation of the vitamin, compared with the effect of a single portion of white bread, containing very little vitamin B.

Pyruvic acid is also very toxic to the brain, and in severe polyneuritis in the rat, congestion, hemorrhage, and tissue damage have been found in centers which are concerned

with muscular coördination and with sensations of taste, thus proving conclusively that the convulsions and loss of appetite have their origin in the central nervous system.

The spectacular cure effected in a few minutes or even a few hours does not restore a very polyneuritic animal to full health. A rat may have been left in the evening eating the food and apparently well, and yet the next morning it may be found dead. The changes in the nervous tissue are not healed as soon as combustion of pyruvic acid is again possible, and liberal doses over a considerable time must be given to restore the tissues to normal condition.

Maintenance of Appetite

The loss of weight in young animals deprived of vitamin B results in their death before they have time to develop symptoms of polyneuritis. Older animals will live for a much longer time and die with marked signs of the nerve disease. Study of the food intake of these animals gives an explanation of the difference in length of life. The food intake of two animals lacking vitamin B, as compared with the normal controls, is given in the table below.

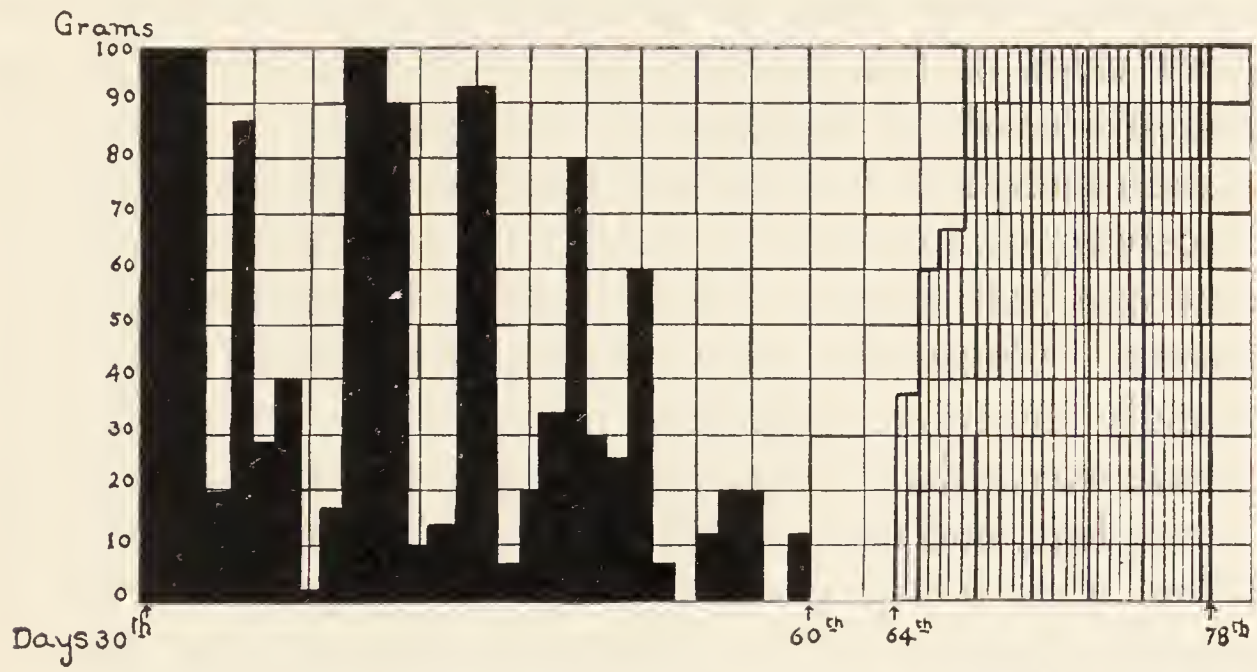
Food Consumption of a Pair of Rats Placed at Weaning Time on a Normal Diet, Compared with That of a Similar Pair Given a Diet Lacking Vitamin B

Date	Weights of Rats Lacking Vitamin B Grams		Food Intake per Gram of Rat per Day Grams	Weights of Normal Rats Grams		Food Intake per Gram of Rat per Day Grams
	Male	*Female*		*Male*	*Female*	
June 30	38	36	—	38	33	—
July 7	41	42	0.065	61	43	0.081
July 14	43	45	0.050	82	54	0.092
July 21	39	41	0.039	89	66	0.073
July 28	37	39	0.030	104	74	0.058
Aug. 4	35	36	0.019	110	78	0.042
Aug. 11	29	Dead	0.016	126	87	0.052

The dog's appetite is also sensitive to lack of vitamin B. Cowgill, Rosenberg, and Rogoff [1] found that an animal de-

[1] Cowgill, G. R., Rosenberg, H. A., and Rogoff, J. "Studies in the Physiology of Vitamins. XV. Some Observations of the Effect of Administration of the Antineuritic and Heat Stable Factors on the Anorexia Characteristic of the Lack of the Vitamin B Complex." *American Journal of Physiology*, Vol. 96, page 372 (1931).

prived of vitamin B would for a time consume all the food offered in a very few minutes, normal dog fashion, then become less interested in his food, eating perhaps a part of it in the course of some hours, and finally lose the impulse to eat entirely. At this point a dose of vitamin B would promptly bring back the former keen appetite. Food refused in the morning would be ravenously consumed later in the day after administration of vitamin B. No such effect fol-



(*After Dr. G. R. Cowgill*)

Fig. 72.—Food intake of a dog kept on a vitamin B free diet for 60 days. On the sixtieth day it was given 10 grams of beef extract, with no improvement in appetite. On the sixty-fourth day one 5 gram dose of a vitamin B concentrate was given. There was immediate improvement in appetite, which continued through the seventy-eighth day.

lowed administration of beef extract, showing that the taste of the food was not the explanation of the difference.

Control dogs, given a sufficient amount of vitamin B daily, have been maintained in Cowgill's laboratory in excellent condition as long as a year and a half. As a result of these experiences Cowgill has come to the conclusion that "the appearance of this characteristic subtle loss of appetite for the experimental ration is in most cases the first definite sign that a state of vitamin B deficiency exists in the experimental animal." Further proof that vitamin B is the specific factor involved in loss of appetite is afforded by the fact that the urge to eat can be restored by introducing the

vitamin directly into the blood stream instead of giving it by mouth.

There are many cases on record in which the appetites of presumably well fed infants have been improved by an increase in the supply of vitamin B in the diet. The possibility of vitamin B deficiency in infants was suggested to Dr. B. R. Hoobler of Detroit after observation of infantile beriberi on a visit to the tropics. "It seemed to me," he wrote upon his return, "that many of the symptoms of mild and incipient cases of this disorder had their counterpart in the children's wards of hospitals in this country." [1] The most common symptom was lack of appetite. Infants suspected of receiving an insufficient amount of vitamin B were given about one half teaspoonful daily of a brewer's yeast concentrate. Those who were refusing portions of their food gradually increased their food intake when the yeast concentrate was added. There was also a certain type of stiffness in arms, legs, and neck which quickly subsided on vitamin B feeding. One infant, given one half teaspoonful of brewer's yeast concentrate daily had changed in two weeks "from a thin, pale, spastic, restless, whining infant, refusing part of its formula, to a happy, rosy-cheeked, smiling baby whose appetite seemed never to be completely satisfied and whose gain in weight was remarkable." Hoobler recommends that "just as regularly as orange juice and cod liver oil are prescribed one should also prescribe a substance rich in vitamin B for the infant dietary."

Maintenance of Good Digestion

When pigeons deprived of vitamin B are forcibly fed, the food remains in their crops and does not digest. When dogs begin to show signs of paralysis after a period of vitamin B deficiency, they frequently vomit and have a foul breath. McCarrison [2] long ago called attention to the prevalence of gastro-intestinal disorders among civilized peoples in con-

[1] Hoobler, B. R. "Symptomatology of Vitamin B Deficiency in Infants." *Journal of the American Medical Association*, Vol. 91, page 307 (1928).

[2] McCarrison, Robert. "Faulty Food in Relation to Gastro-intestinal Disorders." *Journal of the American Medical Association*, Vol. 78, page 1 (1922).

(*Courtesy of Col. R. McCarrison*)

Fig. 73.—A monkey fed for 55 days on a diet lacking vitamin B. The wrist is paralyzed and shows a characteristic "wrist drop." It is trying to capture body fleas and seems unaware that the tip of the first finger and thumb do not touch each other. One leg also tends to give way under the weight of its body so that the erect position is held with difficulty.

trast to the freedom of certain more primitive races from such disturbances, and attributed the difference to the diet. "It is the gastro-intestinal tract, the functions of digestion, absorption and assimilation that are among the first to fail in consequence of faulty food. These are the signs that our ship is running upon the rocks and, as good pilots, we must be aware of them. I often think that we are apt to assume more readily the office of salvors of wrecks than of pilots whose function it is to prevent them." McCarrison took thirty-six wild monkeys, captured in the jungles of Madras, used twelve as controls on a normal diet, and put the rest on experimental diets. When vitamin B was deficient there was great disturbance of the motor functions of the intestinal tract and impairment of the mucous lining which reduced its ability to resist the inroads of bacteria and protect the body against infection.

In Cowgill's dogs, even before lack of appetite manifested itself at all, stomach contractions were less vigorous, and when appetite failed completely, the stomach was practically inert. On receiving vitamin B, gastric activity improved along with recovery of appetite, but did not attain full vigor for a week.

Rats show the same depression of digestive activity, when observed by means of the X-ray, not only in the stomach but also in the intestines, the emptying time of the stomach and small intestines being half again as long, and that of the large intestine about twice as long in vitamin B deficient animals as in normal ones. It has also been found that a food pellet impregnated with charcoal will pass through the alimentary tract of normal animals in three to seven days, but that in case of rats deprived of vitamin B it takes as long as 24 days. A third type of evidence is obtained from injecting fluid into the colons of rats on diets lacking vitamin B and comparing the volume with what could be held by normal rats, a large majority of the animals deprived of the vitamin having colons so relaxed that they could receive twice the amount possible for normal ones. And

finally, a study of the amount of bran necessary for normal elimination in a rat showed that when the bran was deprived of its vitamin B twice as much was necessary as when the natural product was fed.

Similar observations have been made on human beings by Dr. A. A. Fletcher and Dr. S. Graham at the University of Toronto Hospital. Forty patients with chronic arthritis (a disease in which digestion is often impaired) who had very greatly relaxed and sluggish intestinal tracts, showed remarkable improvement when large doses of vitamin B in the form of yeast or wheat germ were administered. The synthesis of vitamin B has made it possible to obtain large quantities at relatively low cost and has greatly facilitated clinical studies. Vorhaus and Williams have recently reported eight cases specially selected for treatment because of poor tonus of the alimentary tract, with the failure of appetite and sluggish elimination which are almost inevitable accompaniments of such a state. They were given liberal doses of the vitamin and in all normal appetite was restored and weakness disappeared. Six of the eight were completely cured of constipation and the remaining two showed definite improvement.

All of these studies tend to confirm McCarrison's view that many of the digestive disturbances afflicting people who do not call themselves sick, but who take various remedies for "sour stomach," "morning mouth," headache, or constipation, might find their digestion improved by increasing their intake of vitamin B. Children need a high vitamin B intake for growth but grown people need liberal supplies also for the health of the alimentary tract. As they advance in years and cut down their calorie intake to adjust to lowered physical activity, they need to see to it that their supply of vitamin B is still kept at the optimum.

The Promotion of Growth

The failure of appetite and disturbance of digestion which quickly result from complete deprivation of vitamin B in-

evitably affect growth. If a young rat be weaned at the age of 28 days from a mother on an adequate diet and then be given in its ration everything needed for growth except vitamin B, it will continue to grow for a few days, until the small reserve of the vitamin in its body is exhausted, and then it will quickly decline, dying in about four weeks. From lack of nourishment the animal will become greatly emaciated and will not live long enough to show very clearly the most characteristic symptom of vitamin B shortage, polyneuritis. There will, however, be some evidence of this in the distortion of the spinal column and consequent humping of the back which may be seen in Fig. 69.

A single dose of a vitamin B concentrate will produce signs of returning health in a very few hours. The animal becomes interested in food and drink, the nervous symptoms are allayed, and the rapidity with which growth is resumed is truly amazing. The growth curves for the animals portrayed in Fig. 69 are shown in Fig. 70. The speedy decline in weight of the animal without vitamin B, and its recovery when on the verge of death, are typical of experience with hundreds of animals under similar circumstances.

There have been many observations of the importance of vitamin B for the growth of human infants. As long ago as 1918, Osborne and Mendel called attention to the danger of feeding infants diluted top milk with added sugar or other form of carbohydrate food. "Under these circumstances," they said, "the child is supplied with a food that contains a relatively smaller proportion of the water soluble vitamine than does the original cow's milk. While milk thus modified may contain sufficient vitamine as long as the food intake is normal, if for any reason the child's appetite fails, the vitamine supply is reduced and endless dietary troubles may easily result." [1]

Doctor J. H. Dennett, a distinguished New York pediatrician, observed a period between the ages of five and ten

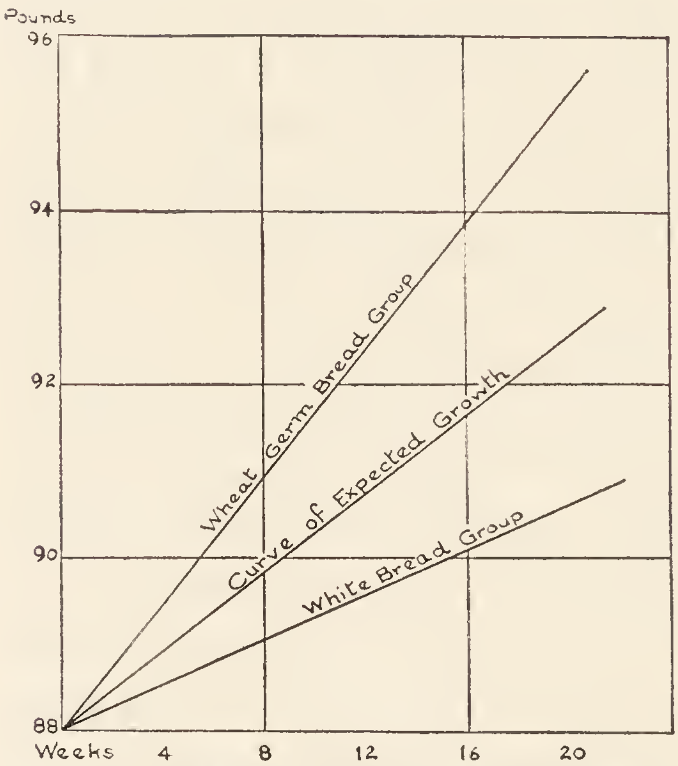
[1] Osborne, T. B., and Mendel, L. B. "Milk as a Source of Water-Soluble Vitamine." *Journal of Biological Chemistry*, Vol. 34, page 537 (1918).

months when many artificially fed babies given orange juice and cod liver oil and otherwise fed according to modern standards grow poorly or cease to gain, become fretful, flabby, and pale, and either lose their appetites or fail to assimilate their food properly. To see whether lack of vitamin B was the cause of the trouble, in 1929 he fed a large number of infants a preparation of vitamin B made from wheat germ as an addition to a modified milk formula. The babies that were adjudged well at the start, 129 in number, showed in the course of a few months a surprising freedom from appetite disturbances and their gains in weight were considerably above the average for their age, while the babies that were already showing symptoms of some deficiency, 29 in number, "did exceedingly well," had good appetites by the end of the first month and at the end of five months had firm muscles and good color, had made up their lost weight and compared favorably with normal infants of their age.

Doctor A. P. Bloxom of Nashville, Tennessee, made a similar study this same year, and came likewise to the conclusion that there is a partial deficiency of vitamin B in infants fed diluted cow's milk with no additional source of vitamin B except a little orange juice. He reported that "thin, scrawny babies become satisfied and contented" and show marked increase in rate of gain when given daily some additional vitamin B in the form of brewer's yeast.

To see whether older children on a more varied diet would be benefited by more vitamin B, Dr. A. F. Morgan of the University of California with Miss M. M. Barry, fed a group of undernourished school children between 11 and 13 years of age as a part of their school lunch, two rolls daily, made with 50 per cent of white flour and 50 per cent of wheat germ, and compared their growth with that of a control group fed the same number of rolls made from white flour only. The children formed a Health Club made up of two teams—Alpha taking the wheat germ rolls, and Beta taking the white rolls. A feeding experiment using white rats was included in the activity of the Club, and the differ-

ences between the rats fed wheat germ rolls and those fed white rolls (in each case plus a little milk) was so impressive that none of the children wished to remain in the white rolls group and the groups had to be reversed after a suitable period. The increase in weight of the wheat germ group was approximately three times that of the white rolls group, and gains in height, though not so striking, were significantly greater in the wheat germ group.



(*Courtesy of Professor Agnes Fay Morgan*)

Fig. 74.—This chart shows the average increase in weight of a group of twelve-year-old school children receiving daily as supplementary food two wheat germ bread rolls, in comparison with a control group fed a similar amount of white bread rolls.

These and other experiences too numerous to mention make clear not only the advantage of liberal vitamin B intake for the best growth, but also the danger that poverty or carelessness may deprive children of a sufficient amount of a factor which may be more easily and economically secured from the germ of cereal grains or from yeast, than in any other way we know at present.

Reproduction and Lactation

Animals severely restricted in their vitamin B supply, but given enough to exist for a considerable time, show changes in many glands, such as the pancreas, the thyroid, and the adrenals. Some of these changes are associated with the undernutrition resulting from lack of appetite, but some are undoubtedly more specific. This is especially true of the sex organs. There are degenerative changes in both testes and ovaries. The males lose sexual interest and the females show complete cessation of the estrus cycle, before a decline in body weight sets in. By artificial injection of the estrus

producing stimulus, the ovarian follicular hormone known as estrin, it has been shown that the reproductive failure is not due to inability to respond to the hormone, but to failure of the body to produce it.

Women who have beriberi seldom bear children. Those with a less severe restriction of vitamin B may produce apparently normal babies, but the dietary deficiency will be revealed during lactation, since both mother and child may develop beriberi when the mother's low supply comes to be shared with the baby.

In the laboratory, experiments have shown that rat mothers on diets deficient in vitamin B have few and feeble young, and that nearly all die before weaning, about half of them during the first week of life. Those that seem normal at first live the longest but die later of paralysis or convulsions or sudden heart failure. When the mothers have a little more vitamin B, but still not an optimum supply, the young survive longer but never attain normal weight and seldom live more than a few weeks. They show such symptoms as disturbance of the circulation and hemorrhages in the brain, intestines, liver, lungs, kidneys, and bones; muscular tremors; enlargement of the heart and a greatly retarded heartbeat; and often die of paralysis. Large doses of vitamin B are necessary to save them.

The need of the young for vitamin B is much greater per unit of body weight than that of adults. The higher the basal metabolism and the more rapid the rate of growth, the greater the requirement. It has been found that a rat mother needs from three to five times as much vitamin B to nurse a litter successfully as she would require for her own maintenance alone.

Less vitamin is needed when given directly to the young; it is estimated that the lactating mother wastes over half the daily supply of vitamin B in transferring it to the milk.

According to Dr. I. G. Macy of the Children's Hospital of Michigan in Detroit, who has made extensive studies of the vitamin content of human milk, it is at best not a rel-

atively rich source of vitamin B. Hence the surest way to protect the young is to administer an adequate amount of the vitamin directly to them. Aside from the fact that transfer of the vitamin is poor, the growing organism needs so much more of the vitamin in proportion to its size than the adult that every precaution should be taken against any scarcity. A surplus will do no harm; a shortage may work incalculable mischief. It is fortunate that suitable concentrates for addition to any infant's diet are now readily available.

Resistance to Infection

Some evidence that lack of vitamin B may seriously impair the mucous lining of the intestinal tract in addition to retarding normal activity comes from a study of gastric ulcer in rats made by Dr. C. Dalldorf and M. Kellogg at Columbia University in 1928. In a group of 37 rats fed a vitamin B-deficient diet, 26 developed one or more ulcers, while in a group of 20 fed a normal diet, all were free from gastric disturbance of any kind. This same year Dr. W. B. Rose at Yale University, somewhat by accident, observed a connection between vitamin B deficiency and susceptibility to infection. A dog deprived of the vitamin developed severe convulsions. In order to save it, a concentrate of vitamin B was injected subcutaneously. The nervous symptoms were promptly alleviated but a few days later an abscess developed at the point of injection. Large doses of vitamin B were then administered, and recovery was rapid.

The organism causing the trouble was a gas producing bacillus known as *Bacillus aerogenes capsulatus*. In order to test the case further normal dogs on an adequate diet were inoculated with this organism. No untoward symptoms followed. They were then put on a diet lacking vitamin B, whereupon the gas bacilli were found in the blood. Again vitamin B was given liberally and the blood cultures became negative. That a liberal supply of the vitamin is essential to full protection is indicated by the fact that when

the animals were fed just enough of the vitamin to maintain a perfect appetite and to gain in weight frequent positive blood cultures were obtained, whereas with large doses they remained negative for months.

Pigeons as well as dogs appear to be more susceptible to bacterial invasion when vitamin B is not liberally supplied. In 1930 Dr. O. W. Barlow of Western Reserve University made a study of the bacteria in the blood of pigeons on deficient diets and found the number of intestinal bacteria per cubic millimeter of blood was greater on vitamin B-deficient diets than any other inadequate diet tested. When a polished rice diet was supplemented with plenty of vitamin B, the invasion of bacteria from the intestines was stopped.

The routine use of liberal amounts of vitamin B now seems to be clearly indicated as a means of enhancing and preserving the efficiency of the alimentary tract. As Cowgill has aptly said, "In case of doubt with respect to a shortage of vitamin B playing a rôle the test is simple and harmless and consists not merely in regulating the diet—a therapeutic measure that exerts its beneficial effect slowly—but in administering large amounts of the missing factor immediately and thus securing a prompt answer to the question." [1]

Measurement

Pigeons are very sensitive to deprivation of vitamin B and show signs of polyneuritis in three to five weeks when fed on white rice. Sometimes there is rapidly increasing weakness and paralysis; sometimes the typical head retraction appears (cf. Fig. 67). Doctor Harriette Chick and Miss Margaret Hume of the Lister Institute, London, testing many foods to find the smallest amounts which would cure pigeons made polyneuritic by vitamin B deprivation, found that aside from yeast some of the richest natural sources of vitamin B are wheat germ, of which 1 to 2.5 grams daily are required; wheat bran of which 5 grams are needed, and rice bran of which 5 to 10 grams are needed.

[1] *The Vitamins.* American Medical Association, page 62 (1932).

The smallest daily dose required to prevent the appearance of polyneuritis in pigeons has also been studied. The amount of wheat germ is about the same as is required for a cure, 1.5 grams daily, while of liver or egg yolk 2 grams per day are necessary.

While some investigators choose pigeons for the measurement of vitamin B others prefer rats, as being more convenient and less variable in their response to deprivation of the vitamin. When young rats, weaned from mothers on an adequate diet at the age of 28 days, are put on a vitamin B free diet they grow fairly well for a week or so, then decline in weight rapidly and die in about a month. As in case of vitamin A, growth ceases when the reserves in the animal's body are exhausted but this occurs much sooner in case of vitamin B than of vitamin A, since the body is incapable of storing much vitamin B. A dog's reserves are exhausted in about a month, and a man's in the course of two or three months.

Sherman and Chase have developed a technic for the use of rats in the quantitative determination of vitamin B in foods which has been used for the measurements reported in Table I in the Appendix. They take as a unit that amount which, when fed daily to a standard test animal whose vitamin B reserve has been exhausted on a standard B-deficient diet, is just sufficient to induce an average gain of three grams per week during a test period of four to eight weeks. Since vitamin B has only recently been separated from the other vitamins in the vitamin B complex, many of the earlier studies will have to be repeated under the conditions prescribed, taking care that all other members of the complex are adequately supplied, before the vitamin B content can be accurately known. An international unit in terms of the pure crystalline product has not yet been established. At present comparisons are made with 10 milligrams of a standard rice polish extract, which according to Williams contains 0.005 milligram of vitamin B. A Sherman-Chase unit is equivalent to approximately one half this amount.

Sources

While vitamin B occurs in many foods, it is lacking in such major sources of energy as white flour, rice, macaroni, starches, sugars, and fats, and is not present in large amounts in any meats except pork, heart muscle, and glandular organs. It is easy to have an attractive diet adequate in calories, protein, phosphorus, iron, vitamins A and G which is very low in vitamin B, as the following dietary indicates:

	Calories	Vitamin B Shares
Breakfast		
Prunes	100	2.5
White farina	100	0.1
Cream	200	—
Toast (white bread)	100	—
Butter	100	—
Coffee	—	—
Cream	50	—
Sugar	50	—
Lunch		
Beef steak pie	400	2.0
Beets	100	1.6
Lettuce salad with French dressing	50	1.8
Rolls, white	100	—
Butter	100	—
Cake	200	—
Coffee	—	—
Cream	50	—
Sugar	25	—
Dinner		
Roast lamb	250	4.0
Mashed potatoes	200	0.4
Broccoli	75	4.0
Celery	10	—
Apple pie	300	2.1
Butter	100	—
Rolls, white	50	—
Coffee	—	—
Cream	50	—
Sugar	25	—
Total	2,785	18.5

The simple change from refined to whole grain cereals in this dietary will increase the vitamin B 100 per cent and in this respect change it from an inadequate to an adequate

diet. Or instead of using the whole grain cereals the addition of one half an ounce of wheat germ to the refined breakfast food will accomplish the same result. When the cereals are heated dry so that a large surface is exposed to a high temperature, a considerable amount of the vitamin B may be lost. In baking whole wheat bread, Morgan found that the loss was very slight. The cooking of a breakfast cereal such as oatmeal or rolled wheat with moist heat at boiling temperature results in a loss of about 15 per cent. In the steaming and toasting to which bran is subjected to produce a crumbled breakfast food about half of the vitamin B is lost. Hence the best dependence for vitamin B in cereals is on the whole grain breads or on the wheat germ which requires no heating.

Next to the cereal grains, one of the great common sources of vitamin B is the legumes. Fresh peas and Lima beans are excellent sources, one eighth cup of peas furnishing as much as one half-inch slice of whole wheat bread from a pound baker's loaf even after making allowance for loss of one fourth of the vitamin in cooking for only 15 minutes.[1] The dried legumes are about one half as rich as fresh peas, one fourth cup of cooked dried whole peas being equal to one half-inch slice of whole wheat bread. Among other vegetables which are to be regarded as good sources are spinach and carrots. One half of a cup of cooked spinach or one cup of diced carrots will furnish about as much vitamin B as one half-inch slice of whole wheat bread.

Other losses in cooking which have not been mentioned above are losses due to dissolving in water which is thrown away and the addition of soda, which increases the rate at which the vitamin is destroyed.

Fruits are as a rule low in vitamin B and the losses in cooking may be considerable. Robb, Vahlteich, and Rose [2]

[1] Rose, M. S., and Phipard, E. F. "Vitamin B and G Values of Peas and Lima Beans under Various Conditions." *Journal of Nutrition*, Vol. 14, page 55 (1937).

[2] Robb, E., Vahlteich, E. McC., and Rose, M. S. "A Study of the Vitamin B Intake of Nursery School Children." *The American Journal of Diseases of Children* (in press, 1938).

FIG. 75.—Foods Yielding about 50 Units of Vitamin B.

	Grams		Grams
Lettuce, head	132	Carrots	129
Broccoli, cooked	135	Banana	266
Bran, prepared	32	Cabbage	100
Tomatoes, canned, strained	74	Wheat germ	4
Orange juice	63	Eggs	89

found that of four nursery school children whose diets were assayed for vitamin B the one with the highest proportion of fruits and vegetables had the lowest vitamin B intake. A very low yield from cereals and less than the amount received by the other children from milk was not compensated by the higher proportion of the total calories from fruits and vegetables.

In the egg vitamin B is confined to the yolk, two yolks being equivalent to a half-inch slice of whole wheat bread.

Milk varies considerably in vitamin B content. The value adopted in this book is the one Dr. F. L. MacLeod found for fresh milk of the best grade, taking samples at different seasons of the year to make the final average. On this basis about one pint of milk is required to furnish the same amount of vitamin B as two eggs.

Among meats, pork muscle is an exception to other muscle meats, being five or six times as rich as beef muscle. Heart muscle contains about ten times more than skeletal muscles. Liver and kidney are very good sources, liver being about four times as rich and kidney five times as rich as steaks, roasts, or chops of meat other than pork.

Drying does not seem to affect this vitamin unfavorably. Yeast, tomatoes, spinach, cabbage, turnips, carrots, and milk have all been dried without loss of vitamin B.[1]

The richest natural source of vitamin B is dried brewer's yeast, of which one gram may contain as much as one ounce of whole wheat. It is difficult to give an exact value for yeast, since different strains and different conditions of growth give rise to very large variations in the vitamin B value. A strain of great potency has been found to yield as high as 800 units per gram.

Requirement

Not many years ago it was assumed that, if calories and protein were adequately provided, minerals would take care

[1] For detailed information on the effect of canning on vitamins, consult Kohman, E. F. *Vitamins in Canned Foods*, National Canners Association, Research Laboratory Bulletin No. 19-L, Revised (1929).

of themselves. Then came convincing experimental work to show that the American dietary was all too likely to be deficient in calcium; that in certain regions there was real danger of deficiency in iodine; and that deficiency in phosphorus might be quite as disastrous to good bone and tooth development as deficiency in calcium. Similarly since the discovery of the vitamins, the idea has been more or less prevalent that while it is very necessary to give attention to the amounts of vitamins A and D, the securing of an adequate supply of vitamin B is a comparatively simple matter. As the effects of vitamin B upon health and growth have been studied, however, it now appears likely that in the ordinary American diet in which a large part of the total energy is derived from refined cereal products, fats, sugars, and meats, shortage of vitamin B may occur as commonly as shortage of calcium, and perhaps oftener than shortage of vitamin A.

In case of the vitamins, the range between a minimum which will support growth to maturity without any marked evidence of deficiency and an optimum which will insure the best health possible at all times with better growth and protection against infection is far wider than in case of calories, protein, or minerals. Increasing growth and well-being in rats have been found to follow increasing dosage from the minimal amount that would protect against polyneuritis up to many times that amount.

The studies of the influence of vitamin B on appetite and digestion have demonstrated that many infants and children are benefited by a liberal vitamin B intake. Thus Daniels found that raising the orange juice in a modified milk formula from 15 cc. to 45 cc. resulted in gains in weight when the diet appeared adequate in vitamin C with 15 cc. and the only other factor in the diet materially increased appeared to be vitamin B, and this view was confirmed later by similar success with yeast extract and also with wheat germ extract.

The study by Morgan and Barry of the influence of added

vitamin B on the growth of children 11 to 13 years of age showed a marked difference when the vitamin was increased (Fig. 74). The children with no extra vitamin B gained on the average 0.18 pound per week in the fall period (15 weeks), and 0.14 pound per week in the spring period (12 weeks), while the groups receiving 5 ounces of wheat germ per week gained 0.35 pound per week in both periods.

The vitamin B requirement is closely related to the energy metabolism. Cowgill and his associates showed this by taking adult dogs, whose previous diet had been rich enough in vitamin B to enable their tissues to hold as much of the vitamin as possible and putting them on a diet deficient in this vitamin. The dogs lost their appetite in about 21 days. When the urge to eat was thus lost, some of the dogs were given forced exercise on a treadmill. A preliminary period of training enabled them to run uninterruptedly from 45 to 90 minutes daily without exhaustion. In each case the time required for the development of loss of appetite was decreased from one third to one half the time required when the dogs were not exercised. When the loss of appetite had been corrected by administration of enough vitamin B, further exercise did not cause loss of appetite.[1]

This is in line with the findings of McCarrison and others who have noted that human beriberi is brought on more rapidly if the patients exert themselves and that rats deprived of the vitamin die sooner if exercised than similarly fed animals which have been allowed to remain quiet.

Himwich, Goldfarb, and Cowgill [2] also showed that when the energy metabolism was increased to about twice normal by administration of thyroid gland, complete loss of appetite appeared in 2 dogs in 17 and 21 days respectively, while

[1] Cowgill, G. R., Rosenberg, H. A., and Rogoff, J. "Studies in the Physiology of Vitamins. XVI. The Effect of Exercise on the Time Required for the Development of the Anorexia Characteristic of Lack of Undifferentiated Vitamin B." *American Journal of Physiology*, Vol. 98, page 589 (1931).

[2] Himwich, H. E., Goldfarb, W., and Cowgill, G. R. "Studies in the Physiology of the Vitamins. XVII. The Effect of Thyroid Administration upon the Anorexia Characteristic of Lack of Undifferentiated Vitamin B." *American Journal of Physiology*, Vol. 99, page 689 (1932).

six months later, after the thyroid administration had been discontinued and the dogs allowed time to recover, deprivation of vitamin B did not result in loss of appetite for twice as long in one case and nearly twice in the other. Without the thyroid, the dogs consumed on the average 650 calories daily, and with it, 1,155 calories. The more rapid depletion is attributed to the need of more vitamin B to take care of the extra calories.

Since the vitamin B requirement increases with the rate of growth and with increased energy expenditure, all growing children should have very liberal amounts, and active working men and women should also be generously supplied.

Robb, Vahlteich, and Rose's study of the vitamin B intake of four pre-school children was made on children who had been under supervision in the nursery school of the Child Development Institute of Teachers College, Columbia University, for a full school year and were known to be normal children eating a dietary which conformed to the best modern standards, and making excellent growth records. These children actually ate from 400 to 600 Sherman-Chase units of vitamin B daily, or 13 to 46 units per 100 calories. In Rose and Borgeson's study of a group of 60 Manhattanville nursery school children the vitamin B intakes ranged from 250 to 600 units per day, in a week's weighed dietary, or 10 to 45 units per 100 calories, the majority receiving between 20 and 35 units per 100 calories. The estimates are probably somewhat high as they do not take account of losses in cooking. The children were under very careful medical and dietary observation from 8 to 21 months and detailed records were kept regarding their physical development. Growth in height in the large majority of cases was double the Woodbury averages (cf. Tables III and IV in the Appendix) for their respective ages, and their increases in weight were above expectation in fully one third of the cases, the average monthly gain being about the same as that of a group of similar age but from families of much higher economic status. It would seem that 400 to 600 units

per day might be regarded as a liberal allowance for children under 6 years of age, and that requirements for growth and activity for children requiring less than 2,000 calories per day should be covered by 200 units per day. This makes no allowance for the influence of infection, which may very greatly increase vitamin needs. Even with a slight cold the vitamin B intake may well be substantially increased. It should also be increased if appetite or digestion is poor or if vague "growing pains" and restless sleep are troublesome.

An estimate of the vitamin B intake of older children ranging in age from 5 to 15 years in one of the institutions studied by Rose and Gray, where the children's growth and their food intake were followed through several years should throw some light on vitamin B needs. Sixty-eight children whose height-weight records were complete for two consecutive years were graded as to growth progress and the majority found were "good" or "excellent"; of the few "poor" ones, only four were "very poor." The health records and teeth records as kept by the attending physician and dentist were on the whole excellent, so that there was every reason to think the diet excellent, especially as some of the children were maintained on it from early childhood until they finished high school. A study of the dietary for eight months made possible an estimate of the vitamin B intake, and the average per 100 calories was found to be about 15 units. Most of the children's energy requirements lay between 2,000 and 3,500 calories, which would mean at least 300 units per day for the younger ones, and up to 500 units a day for the older ones. A special study of six girls 12 and 13 years old who were under weight revealed that the cause was a low calorie intake, which was remedied by the simple device of increasing the amount of milk and of bread and butter without any other change in the dietary program. Some of the girls were given extra vitamin B but there was no indication that the institutional dietary was deficient in this respect. When a child's diet, adequate in other essentials

includes a quart of milk daily and as much as 300 calories of whole grain cereal in which the vitamin has not been lost by treatment with high temperatures in manufacture, there is good reason to think that it will be adequate in vitamin B. The modern tendency to use orange or tomato juice rather liberally for vitamin C also increases substantially the vitamin B intake.

Adult requirement for vitamin B is also related to energy expenditure. As activity increases it is advisable, therefore, to select as additional energy-yielding foods those which contain vitamin B in preference to those which furnish little, if anything, besides calories, as for example sugar and highly milled cereal products. When beriberi was eradicated from the Japanese navy by substitution of 10 ounces of whole barley for the same amount of rice, this change gave the men about 10 Sherman-Chase units of vitamin B per 100 calories of food. For a 3,000 calorie diet this would mean 300 units, which in a moderately priced American diet can be obtained from such dependable sources as a pint of milk, 200 calories as whole grain bread or cereal, 200 calories as potatoes, an egg and half a cup of tomato juice. Sherman recommends food habits which will result in an intake considerably higher. He says, "If half of the needed food calories are taken as fruits, vegetables, milk, and eggs, and if half of whatever breadstuffs and cereals are used are taken in the whole-grain, or 'dark' or 'unskimmed' forms, there will almost certainly be provided an ample supply of vitamin B—and of many other important nutritional factors as well." [1] Estimated on the basis of a sedentary man needing 2,800 calories, this would mean about 700 calories from fruits and vegetables and a quart of milk a day, which is two or three times as much of each as is ordinarily eaten by well-to-do Americans. A very conservative allowance of cereal foods in such a diet would be 15 per cent of the total calories, of which 210 calories would, according to Sherman's plan, come from whole grains. The milk would yield at least 100 units, a good assortment of fruits and vegetables

[1] Sherman, H. C. *Food and Health*, page 129. The Macmillan Co. (1934).

200 units or more, and the whole grain cereal 100 or more, making a daily total of between 400 and 500 units.

This type of diet, while insuring liberal intakes of all protective factors, is more expensive than many people can afford, and it is well to bear in mind that the same results so far as vitamin B is concerned can be attained in low priced diets by more use of the whole grain cereals and legumes; or if the calories they furnish are not desired, by suitable quantities of the bran and germ of grains.

There are many conditions in which a specially liberal intake of vitamin B is necessary, either because of heightened metabolism or because there is some disturbance in the alimentary tract which interferes with absorption of the vitamin. Absorption is disturbed in sprue to such a degree that successful treatment necessitates injection of the vitamin directly into the blood vessels. In Eijkman's laboratory in Batavia, Java, there is always kept on hand a supply of pure crystals for injection in advanced cases of beriberi or other conditions in which the vitamin cannot be absorbed from the alimentary tract. According to Cowgill, many cases of beriberi have followed prolonged fevers and gastro-intestinal disturbances. When patients are subsisting on rations barely sufficient in vitamin B, any shortage of food or any increase in metabolism, due to fever or hyperthyroidism will throw the balance in the wrong direction.

Vorhaus and Williams, from their studies of pathological conditions, recommend large amounts of vitamin B in gastro-intestinal disturbances, neuritis, fever, overactivity of the thyroid gland, diabetes, and tuberculosis. Any diet in which total calories are restricted should be enriched in vitamin B so that the amount taken will at least be equal to that on a full diet. For the pregnant woman it would seem advisable at least to double the normal intake. The Commission on Nutrition of the League of Nations [1] appointed to set up physiological standards as a guide to nutrition programs in

[1] League of Nations. *The Problem of Nutrition, Vol. II. Report on the Physiological Bases of Nutrition* (1936).

various countries, recommended a minimum food selection which without whole grain cereals would yield about 300 units per day; with half the cereals in such a diet from whole grains this could easily be raised to 500 or 600 units. In lactation a liberal supply is important, and 600 units a day should be considered a minimum.

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CHAPTER XII

VITAMIN C AS A REGULATOR OF BODY PROCESSES

Discovery

It is again necessary to turn back the hands of time many centuries, to the period when scurvy was a constant menace to sailors, soldiers, and explorers, and at intervals swept over great areas of land, especially in northern regions where people had to subsist for a large part of the year on a diet consisting mainly of grain products and meat or fish. The French crusaders are reported to have suffered greatly from it in the thirteenth century. On Jacques Cartier's second voyage to Newfoundland in 1535 "he wintered near an Indian village, Stavacona, in Quebec. Both the Indians and his crew were afflicted with scurvy. Between December and the middle of March, 25 men from his crew died, and the rest were so sick that recovery was despaired of except for three or four. The middle of March, Cartier noticed an Indian whole and sound who had been very ill with scurvy ten or twelve days earlier. He asked the Indian how he had healed himself and was told that he had taken the juice and sap of the leaves of a certain tree called 'Ameda.' At Cartier's request, the Indian had branches brought and showed how the bark and leaves should be boiled together and the resulting decoction taken every other day. So successful was the remedy that all Cartier's crew were speedily completely cured, and the narrator goes on to say: 'It wrought so well, that if all the physicians of Montpelier and Louaine had been there, with all the drugs of Alexandria, they would not have done as much in one yere as that tree did in sixe days, for it did so preuaile, that as many as used it, by the grace of God recouered their health.' He explains that the 'Ameda'

is thought to be the sassafras tree, but this incident occurred the middle of March at a season when 'our captaine' was walking from his boat to the shore upon the ice at the time he saw the Indian who had been healed, so the 'Ameda' could not have been a deciduous tree. Lind believed it to be the American spruce." [1]

In 1747, this same Dr. Lind, who was a surgeon in the British navy, conducted a most interesting experiment to compare various articles of diet as to their antiscorbutic properties, using as subjects twelve sailors sick with scurvy on board the "Salisbury," at sea. They had one diet common to all, water gruel sweetened with sugar in the morning, fresh mutton broth oftentimes for dinner; at other times light puddings, boiled biscuit with sugar, etc.; and for supper, barley and raisins, rice and currants, sago and wine, or the like. The men were divided into pairs. One pair had each a quart of cider daily; another, a spoonful of vinegar three times a day. Two of the worst had half a pint of sea water every day; two others had each two oranges and one lemon; two others had a most amazing compound of seeds, gums, etc., with a drink of barley water acidulated with tamarinds. The result of this nutrition experiment was that in six days "the most sudden and visible good effects were perceived from the use of the oranges and lemons." He recommended that thereafter lemon juice evaporated to a syrup should be carried in all ships for the safeguarding of the sailors, and in 1795 regular administration of lemon (called lime) juice was prescribed in the British navy, wherefore British sailors are today familiarly known as "limies." With the introduction of the potato into northern Europe scurvy greatly decreased on land, extensive outbreaks occurring only when crops failed or other misfortune deprived the people of their usual food.

Scurvy was considered a disease of adults, and the recognition of it as a dietary disease was far from universal a

[1] Appleton, V. B. "Spruce Beer as an Antiscorbutic." *Journal of Home Economics*, Vol. 13, page 604 (1921).

hundred years after the rule was made for its prevention in the British navy. In 1878 a famous English physician connected with the London Hospital for Sick Children, Dr. Cheadle, described three cases of scurvy in children under three years of age. Dr. Cheadle had made the North-West Passage, sailing from Liverpool to Quebec in 1862, and hence had traveled across the American continent to the Pacific coast. On these wanderings he "learnt much about adult scurvy, small-pox, starvation, massacres and hairbreadth adventures." Returning to London, he found the doctors groping in darkness for the cause of the dreadful condition of the gums of certain children, and recognized that it was scurvy. Then he asked, why did these children, out of all the number in the hospital, become scorbutic? An inquiry into the diet showed that one child for eight months had had only oatmeal, rusks, and water with a little mutton broth; another for three months had lived on bread and butter with a one-seventh share in a pint of milk together with a patent infant food; the third had been weaned two years and then fed bread, butter, and tea with occasionally some sausage and a little brandy and water. Dr. Cheadle's answer to his own question was "potatoes," which most children of the poor were fed after they were weaned. His treatment consisted of unboiled milk with mashed potatoes beaten up in it, raw meat, and the juice of two oranges.

Five years later another great English physician connected with the same Hospital for Sick Children, Sir Thomas Barlow, published a classic paper "On Cases Described as 'Acute Rickets' which are Probably a Combination of Scurvy and Rickets, the Scurvy Being an Essential and the Rickets a Variable Element." Among the symptoms noted in one of the children were an excessively pale, sallow complexion, flabby muscles, continual moaning with a tendency to shriek when approached due to a "deep-seated pain connected with the bones." One of the peculiar symptoms was discovered to be hemorrhages into the muscles and under the periosteum of the bones of the legs. The diet, which had been

wholly of dried milk and cereal with some beef extract, was changed to a pint and a half of cow's milk daily plus one third cereal gruel or barley water, the juice of a quarter of a pound of raw beef, and two teaspoonfuls of orange juice. In three days there was a notable change and improvement continued until in eight weeks this child could stand upright with a little support, "was of ruddy color and his skin and muscles had become quite firm." A diagnosis of scurvy in the absence of soreness and swelling of the gums was contrary to the classical sign of this disease and to be sure he was not dealing with rickets Sir Thomas referred some of his specimens of subperiosteal hemorrhage to Sir William Jenner who said positively that he had seen no such condition in rickets. So the conclusion was reached that while the disease had occurred in rickety children, the characteristic symptoms were not due to rickets at all, but were "truly scorbutic," and that marked improvement followed "a vigorous and especially an early antiscorbutic treatment."

Systematic Study of Antiscorbutic Foods

At the close of the nineteenth century it was known from practical experience that certain foods would cure scurvy and various theories had been proposed to account for the antiscorbutic power of these foods, none of which had proven tenable. Then in 1907 two Norwegian investigators, Holst and Frölich of the University of Oslo, stimulated by the success of Eijkman and others in producing experimental polyneuritis in pigeons by a faulty diet, undertook similar experiments in the hope of finding the causes of ship beriberi. This had become suddenly prevalent among Norwegian sailors, Holst states, because about 1894, in response to public demand, shipmasters were compelled to supply sailors with bread made from white wheat flour in place of rye flour milled without removal of the germ, as had been customary up to that time.

Instead of pigeons Holst and Frölich used guinea pigs and found to their surprise that when fed polished rice these de-

veloped, not beriberi, but *scurvy*. Further investigation showed that a diet of oats or any other grain or bread resulted in a scorbutic condition, but the feeding of grain plus a moderate amount of cabbage, dandelion, carrot, potato, or other fresh vegetable prevented the disease. Most significant was their finding that certain foods such as cabbage, carrots, and cauliflower lost their antiscorbutic property on heating or drying, while some others, such as potatoes and turnips and fruit juices, remained antiscorbutic after cooking.

Fürst, working in the same laboratory, experimented with peas, lentils, and almonds, and found that they resembled cereals in their lack of the antiscorbutic substance, but that when soaked and allowed to sprout they developed antiscorbutic properties. He also tried various combinations of seeds, and wisely concluded that "there is no advantage in numerous foods when none contains the needed substance."

The work of Holst and Frölich was rapidly extended by many investigators and by 1918 it was generally agreed that an exclusive diet of cereals or other seeds would cause disturbances in the nutrition of the guinea pig resembling human scurvy. But there was not yet conclusive evidence as to why these foods produced such effects. Uncertainty arose partly from the fact that it was found impossible to induce scurvy in rats, but still more from the readiness with which seemingly slight changes in some foods caused loss of the antiscorbutic property, while similar changes in other foods had no such destructive effect.

The problem regarding the rat's immunity to scurvy was solved by the discovery that rat livers are antiscorbutic even when the animals have subsisted for a long time on a scorbutic diet. When the livers of such rats were fed to guinea pigs very ill with scurvy, the symptoms promptly disappeared and the animals gained rapidly in weight.

The confusion as to whether the antiscorbutic properties of foods depended upon their physical character, their acidity, or some specific chemical substance was cleared up by Hess and Unger in 1918 when they showed that the white

inner part of orange peel was antiscorbutic as well as the acid juice; and also that the antiscorbutic substance could be extracted from orange juice with alcohol and would cure scurvy when given by injection directly into the blood stream. The evidence was now sufficiently clear and convincing that in addition to adequate calories, protein, mineral salts, and vitamins A and B, an adequate diet must also contain an antiscorbutic substance, and in 1920 Drummond proposed that it be called vitamin C.

Isolation and Identification of Vitamin C

In 1921, at the Lister Institute in London, Dr. S. S. Zilva began a long series of experiments to obtain a highly active concentrate from lemon juice by removal of the acid, sugar, and most of the water and salts, and succeeded in making a preparation of this easily destroyed vitamin which would keep for several months if protected from air and light. Aside from the scientific contribution thus made to our knowledge of vitamin C, these researches brought at least one immediate practical return in connection with the British Air Route Expedition to Greenland in 1930–31. It so chanced that for over six months (October to May) one member of the party was isolated from the regular base and had to subsist, after the first month out, mainly on the sledging ration, consisting of pemmican, margarine, sugar, chocolate, cocoa, pea flour, and oats plus a casein preparation for additional protein with occasionally a teaspoonful of condensed milk. To guard against malnutrition, he added daily about one gram each of dried yeast and of a mineral salt mixture such as is used in laboratory studies, and one dessertspoonful of a lemon juice concentrate prepared by Zilva. Every second day he also included a dessertspoonful of cod liver oil. On a ration thus fortified, although forced to reduce the sledging ration by one half as supplies began to run low, and although snowed up completely in his hut from the last of March to the beginning of May, he was able when relieved to ski about one mile unaided to the relief camp, and his teeth and gums

remained in good condition so that he "could throughout bite hard uncooked food without discomfort."

For eight years (1921–29) Zilva pursued his researches, getting still more concentrated solutions of vitamin C, and

(*Courtesy of Professor C. G. King*)

FIG. 76.—Crystals of Vitamin C.

learning more about its properties. Other investigators profited from his reports and in this country in 1927 Professor C. G. King of the University of Pittsburgh, having prepared a concentrate according to Zilva's method, discovered a way to remove still more of the contaminating material. This led to great improvements in the method of concentrating the vitamin so that by August, 1931, King was able to report a concentrate of the active substance of lemon juice over 20,000 times as potent as the original juice. He found, too, that the vitamin was distinctly acid in character and had a strong reducing action. Having now developed methods for such high concentration of the vitamin, the

next goal was its isolation in the form of pure crystals, and this ambition was realized within a few months. In April, 1932, King and Waugh reported the preparation of a crystalline compound from lemon juice which was active in preventing scurvy in guinea pigs. These crystals they found to be a hexuronic acid, a relatively simple chemical compound yielding 6 carbon, 8 hydrogen, and 6 oxygen atoms.[1]

Often in research, independent lines of investigation suddenly converge and many perplexing problems in several fields are thereby illuminated. This has been strikingly so in case of vitamin C. Research on the nature of biological oxidations, and especially of respiration in the leaves of plants, led to the discovery by Professor A. Szent-Györgyi, now of the University of Szeged, Hungary, but at the time working in England at the University of Cambridge, of a substance in the cortex of the adrenal gland, which he identified as hexuronic acid, and suggested might have some relationship to a substance of similar properties which Zilva found in his concentrates of lemon juice but did not believe was vitamin C. It did not seem to Zilva that a vitamin could be as simple as hexuronic acid. But Szent-Györgyi was able to show that the hexuronic acid which he prepared from beef adrenal glands would protect guinea pigs from scurvy in doses of about 0.5 mg. daily, and that 1.5 cc. of lemon juice was equal in antiscorbutic potency to this amount of hexuronic acid. Szent-Györgyi also discovered a very convenient source of hexuronic acid in the Hungarian red pepper from which our commercial paprika is prepared. Many other workers now were eager to extend these findings. They were supplied with sufficient material by Szent-Györgyi and Svirbely. The latter had gone from King's laboratory on a post-doctorate fellowship from the University of Pittsburgh where he had learned King's method of purification of the vitamin and assisted in the preparation of the then almost fabulous amount of a whole pound of ascorbic acid.

[1] Waugh, W. A., and King, C. G. "Isolation and Identification of Vitamin C." *Journal of Biological Chemistry*, Vol. 97, page 325 (1932).

Crystals from lemon juice, adrenal glands, and red peppers were found to agree in antiscorbutic value, and distinguished organic chemists in Europe and America attacked vigorously the problem of chemical structure, which was greatly simplified by knowing that the vitamin belonged to the hexuronic acids, a well known chemical group. Even before every atom had been fitted into its exact place in the ascorbic molecule, synthesis was also accomplished, and the first use was made of chemically pure vitamin C in treating a case of human scurvy, 40 mg. being given a man by intravenous injection and effecting a prompt cure.

In 1933, Professor W. N. Haworth of the University of Birmingham, England, and Szent-Györgyi suggested the name ascorbic acid, and Haworth was able to discover the last detail of structure and publish the correct formula.[1]

In this connection it is interesting to note that as early as 1919, before it was fully proven that there was a vitamin C, McCarrison had reported that guinea pigs on a scorbutic diet manifested changes in their adrenal glands before ordinary signs of scurvy appeared. Since the isolation of vitamin C in pure crystalline form, new studies have shown that both the adrenal cortex and medulla of a normal guinea pig are very rich in vitamin C, but that the gland of a severely scorbutic animal contains practically none. The rat and dog can never be made scorbutic because they cannot be deprived of the ascorbic acid in their adrenals by any dietary measure.

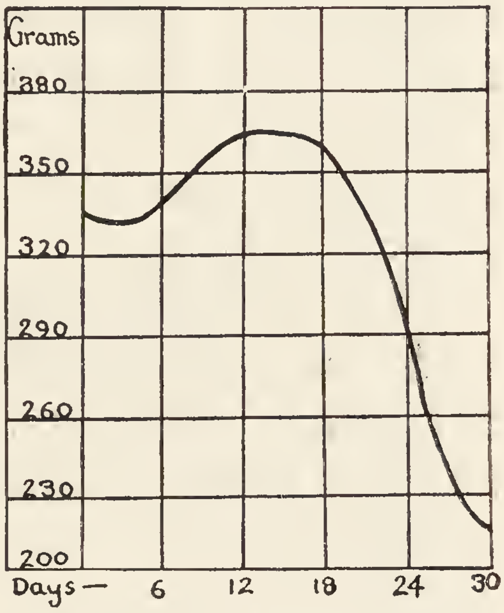
The Prevention and Cure of Experimental Scurvy

As has so often happened in human experience, knowledge of scurvy as a disease and the empirical discovery of a cure long preceded the identification of the antiscorbutic substance. For scientific study of any disease an experimental animal is necessary, in order that conditions may be con-

[1] The term ascorbic acid conflicts with a ruling of the Council of Pharmacy and Chemistry of the American Medical Association, and so they call pure vitamin C "cevitamic acid." The numerical formula is $C_6H_8O_6$. For the structural formula see Sherman's *Chemistry of Food and Nutrition*, 5th edition, page 424. The Macmillan Co. (1937).

trolled and only one factor in a situation be varied at a time. A first step in the discovery of vitamin C was the observation by Dr. Theobald Smith of the Rockefeller Institute for Medical Research, in 1895, that guinea pigs kept upon a diet of oats and no fresh vegetables developed a hemorrhagic disease. However, it was more than ten years before close resemblance between the disease induced in these animals and scurvy in human beings was fully appreciated.

In 1914 Hess and Fish described outbreaks of a subacute type of scurvy in an infant asylum in New York where the children had been fed pasteurized milk diluted with cereal gruel. They were restless, irritable, and retarded in growth. The investigators found, just as Cheadle and Barlow had, that orange juice or a mashed potato was effective as a cure and set aside an old superstition against the tomato as unsuitable food for children, showing that canned tomato juice could be used instead of orange juice even for babies one month old.



(Courtesy of Professor H. C. Sherman and Miss S. L. Smith)

Fig. 77.—Guinea pigs six to eight weeks old and weighing 300 to 350 grams placed on a scorbutic diet continue to grow for about 15 days, then lose weight rapidly and die of scurvy in from 26 to 34 days. The above curve is the average of 10 guinea pigs on a diet lacking vitamin C.

It was not until 1918, however, that a fully convincing demonstration was made by Cohen and Mendel that scurvy could be produced at will in guinea pigs by simply controlling the diet. For example, they prepared a soy bean cracker which contained all the then known essentials of an adequate diet, and which the guinea pigs ate with great readiness. "At first their appearance was satisfactory. On about the tenth day, however, they exhibited a tenderness of the wrist and ankle joints, though they were still eating well and gaining in weight. Then the conditions became more severe. The joints swelled to twice or three times the normal diam-

eter and spontaneous fracture of the wrist occurred in one animal. Appetite diminished and a sharp nutritive decline ensued." [1]

These are today recognized as characteristic symptoms of scurvy. If a healthy young guinea pig weighing about 300 grams is placed on a vitamin C free diet, it continues to grow for about two weeks then loses weight rapidly and dies in from 26 to 34 days. A typical growth record is shown in Fig. 77.

When the weight begins to fall steadily, the joints become tender and swell often to two or three times the original diameter of the bone. The animal becomes relaxed and weak, as shown in Fig. 78, and frequently because its gums and jaws are sore, will lie down with the side of its face on the floor of its cage in a typical "face-ache" position. The jaw bones suffer from absorption and appear eroded, the gums are spongy and bleeding, the teeth become loose and take irregular positions. The roots are absorbed and when the jaw is removed from the body and cleaned, the molars easily fall out, as shown in Fig. 79. In a guinea pig this could not happen unless the bone or cartilage were actually dissolved. The junctions of the ribs with the cartilages show "beads" similar to those in rickets and sometimes rib or leg bones are so brittle as to fracture spontaneously. At other times they fall apart at the joints, owing to the dissolution of the supporting cartilage, a condition easily mistaken for a fracture. The loss of calcium from the body is very great.

Hemorrhages are common in the intestines, kidneys, adrenals, spleen, bladder, bone marrow, and periosteum, under the skin and in the muscles. They are due to interference with the nutrition of the capillaries which results in disorganization of their walls. There is also degeneration of cartilage cells all over the body and even muscle fibers have been found disintegrated.

[1] Cohen, B., and Mendel, L. B. "Experimental Scurvy of the Guinea Pig in Relation to the Diet." *Journal of Biological Chemistry*, Vol. 35, page 425 (1918).

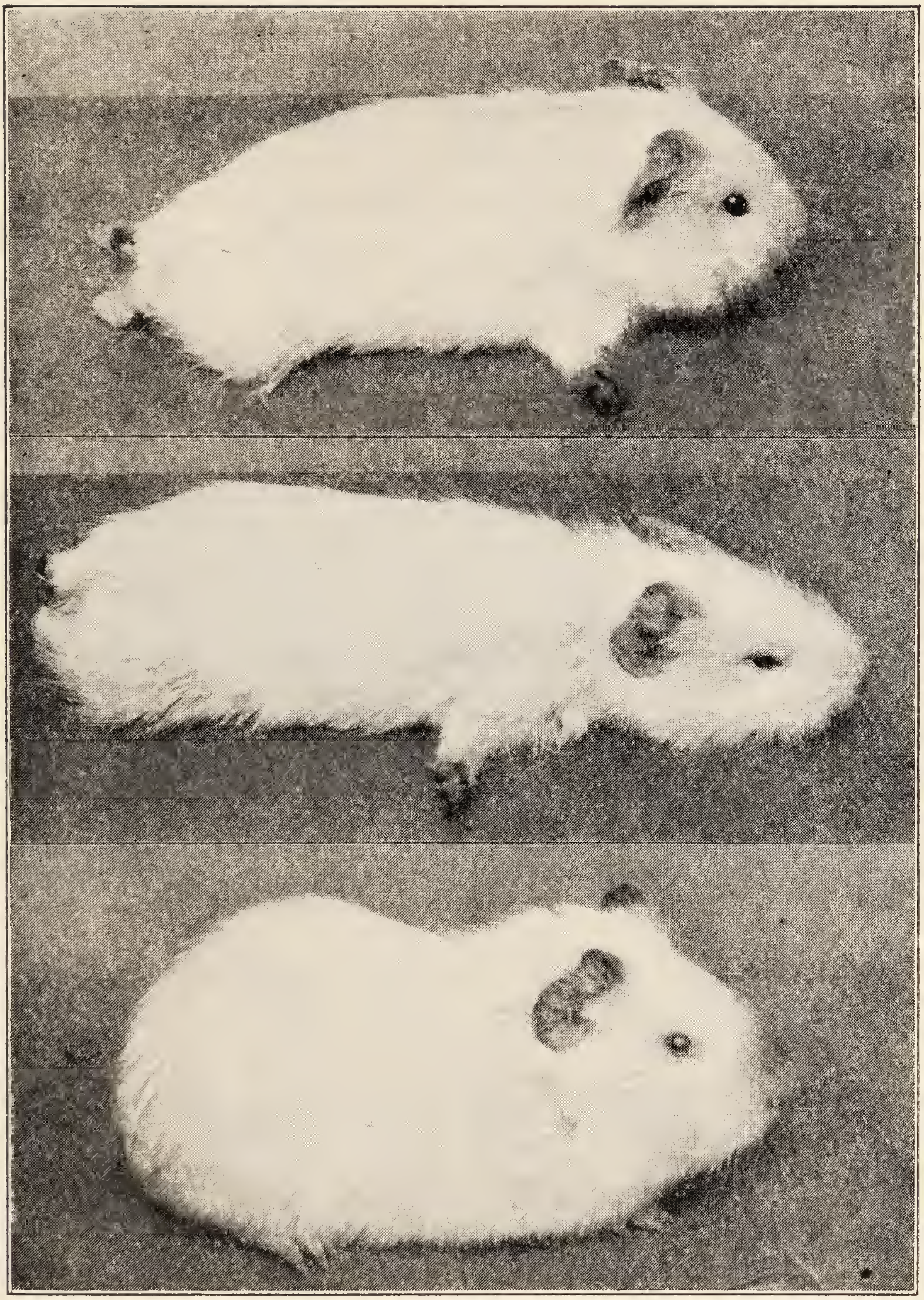


Fig. 78.—The Lowest Animal is Normal. The Two Upper Ones Show Characteristic Positions of the Scorbutic Guinea Pig.

The first preparation of vitamin C from animal tissue was made by Dr. E. C. Kendall of the Mayo Clinic from the adrenal gland, but subsequent study of other organs and tissues has shown that vitamin C is very widely distributed in the animal body. It is highest in glandular tissue, especially in the adrenal, pituitary, corpus luteum, and the thymus of the infant, and lowest in muscle tissue and blood, with the heart, kidney, and lungs intermediate. It has even been identified in the odontoblasts of the teeth. When tissues or organs are low in vitamin C their respiratory activity is markedly decreased, showing that vitamin C is essential

FIG. 79.—The Jaws of Two Guinea Pigs.

The one on the left is from an animal fed plenty of vitamin C; the one on the right, from a scorbutic animal. The deterioration of the jaw bone has permitted the molar teeth to fall out.

to the complex interplay of enzymes and oxidizable materials, involved in the combustion of the fuel foods. Even more easily observable than the relationship to tissue respiration is the influence which vitamin C exerts on the structure of tissues. The widespread degenerative changes all over the body in scurvy have been found by Wolbach [1] and Howe and by others working in this field to be due to the inability of supporting tissues to produce and maintain intercellular substances. Thus vitamin C exercises over cells of a very different type from the epithelial cells so sensitive to lack

[1] Wolbach, S. B. "The Pathologic Changes Resulting from Vitamin Deficiency." *Journal of the American Medical Association*, Vol. 108, page 7 (1937).

of vitamin A, a similarly striking control. This inability of tissues to produce intercellular material is the underlying cause

(1) of the hemorrhages which may occur anywhere in the body
(2) of profound changes in the structure of the teeth and gums
(3) of changes in the growing ends of the bone with beading and other deformities which in earlier times were mistaken for rickets
(4) of the falling apart of bones due to loss of supporting cartilage
(5) of enlargement of the heart and damage to the heart muscles
(6) of degeneration of muscle fibers generally, causing extreme weakness and even death
(7) of the profound anemia due to destruction of blood-forming cells in the bone marrow and loss of blood by hemorrhage
(8) of loss of calcium through degeneration of the bone matrix so that it is no longer able to retain the mineral salts and the bones become so soft that they break spontaneously
(9) of the degeneration of the sex organs.

In fact, the lack of vitamin C is the cause of such widespread disorganization that it is amazing that scurvy can be latent for so long a time before the onset of pain and occurrence of marked outward symptoms. It is also surprising how rapidly improvement follows the administration of the vitamin. In 24 hours new formation of "cement" material has been demonstrated in both bones and soft tissues. Young animals which have become helpless from paralysis in the hind legs soon recover. In the experience of Meyer and McCormick [1] who have made an exhaustive study of the changes in guinea pig scurvy, only those failed to recover whose teeth became tilted and fixed in an oblique position so that they could not eat and died of starvation.

[1] Meyer, A. W., and McCormick, L. M. *Studies on Scurvy.* Stanford University Publication, *Medical Sciences,* Vol. 2, No. 2, pages 133–233 (1928).

In the days when the Roman soldiers were campaigning on the Rhine, they suffered, after the campaign had lasted two years, from loosening of the teeth, and a remedy was discovered in the eating of a native plant thought by modern writers to be some variety of sorrel. Swelling and bleeding of the gums and progressive loosening of the teeth have always been accounted characteristic symptoms of human scurvy, and in their early researches Holst and Frölich noted the same symptoms in guinea pigs. But actual changes in the structure of the tooth itself were first remarked in 1916 by Jackson and Moore, who noted hemorrhages in the pulp of the teeth in guinea pigs. Soon after, in 1919, Zilva and Wells showed that scurvy produced great changes in the teeth of both guinea pigs and monkeys, and discovered that the tooth is one of the first parts of the body to be affected by any shortage of vitamin C. They found that when the mildest degree of scurvy could barely be detected upon post-mortem examination, profound changes in tooth structure had already taken place.

In this country Dr. Percy G. Howe was also actively engaged at this time in studying the effects of diet on teeth, and described changes not only in the gums and pulp, but also in the enamel and dentine which could be cured by addition of orange juice to the diet. Zilva and Wells had noted that the odontoblasts of the teeth of scorbutic guinea pigs became disorganized, and their work was soon extended by Dr. Axel Höjer of Sweden, who in 1924 found that when not enough vitamin C was given to promote growth but only that small amount which would arrest decline in weight for several weeks, changes could still be detected in the teeth by the second week, while on a completely scorbutic diet, they appeared within a week. The first change occurs in the odontoblasts, which make the nutritional connection between the pulp of the tooth and the dentine. These select essential elements from the blood and plasma and convey them in the dentinal lymph to the dentine and enamel by way of fibrils which penetrate fine

tubular canals in the dentine. They then divide into forked branches which pass the lymph to the sheaths enveloping each rod of which the enamel is composed, and so are responsible for the transport of nourishment to all the hard portions of the tooth. When vitamin C is not entirely lacking in the diet but is present in too small quantity, the odontoblasts, which ordinarily stand in a row side by side like the pickets of a fence, lose their orderly arrangement and change their character. They shrink away from the dentine, which in turn begins to degenerate, becoming liquified and later being replaced by "secondary dentine" which is more like bone than like the original dentine. There is also injury to the pulp, sometimes resulting in large hollows filled with fluid. In the guinea pig about twice as much vitamin C is needed for complete tooth protection as for the prevention of the ordinary signs of scurvy.

In the period since Höjer's report appeared, his observations with regard to the odontoblasts have been fully confirmed and greatly extended. A very recent study by Dr. E. W. Fish of the Royal Dental Hospital, London, and Professor L. J. Harris of Cambridge University attributes the damage to the teeth to injury of six different types of cell concerned in tooth development. The enamel forming cells (ameloblasts) are not affected as soon as the odontoblasts nor by as mild a degree of scurvy, but when the disease is severe "they either disappear altogether or become hard and shriveled so that even if the animal is cured there never will be any enamel on that section of the tooth which was forming when the disease was at its height." [1]

The cementum, which covers the part of the tooth imbedded in the jaw, is secreted by cells (cementoblasts) which undergo degeneration, so that no cementum is produced, and its place is taken by a scar tissue with calcium deposits similar to that laid down to protect the pulp (secondary dentine). In short, deficiency of vitamin C appears to affect all cells

[1] Fish, E. W., and Harris, L. J. "The Effects of Vitamin C Deficiency on Tooth Structure in Guinea Pigs." *Philosophical Transactions of the Royal Society of London*, Series B, Vol. 223, page 489 (1934).

concerned with the laying down of the hard tissues—dentine, enamel, cementum, and the bone of the jaw.

Just how all these findings apply to human teeth is not yet entirely clear, but they have served to emphasize the far-reaching rôle of nutrition in tooth health. No animal except the monkey has been found sufficiently like the human being in tooth structure and food requirements to serve as a satisfactory testing agent. Westin, in collaboration with Höjer, studied 18 cases of human scurvy and reported degeneration of the odontoblasts, and changes in pulp, dentine, and cementum similar in many respects to those observed in guinea pigs' teeth. The extensive studies of Lady Mellanby on the relation of the structure of the teeth to dental disease and especially as a factor in dental caries, while largely conducted on dogs which do not get scurvy and hence giving no direct evidence in regard to the rôle of vitamin C, indicate very strongly a definite relationship between poor tooth structure and susceptibility to caries,[1] and the relationship of vitamin C to every kind of tooth building cell justifies emphasis on vitamin C as a factor in tooth health and development.

Changes in the Bones

In his treatise on *Scurvy Past and Present*, Dr. A. F. Hess pointed out as long ago as 1920 that many infants presenting no symptoms of acute scurvy might still be anemic and fretful, weak and retarded in growth because of a subacute or latent form of the disease which no one had learned to recognize. In 1923, a comprehensive study of rickets undertaken in New Haven, Conn., under the auspices of the Children's Bureau of the United States Department of Labor, by Dr. Martha Eliot revealed a number of instances in which unsuspected scurvy was discovered by means of X-ray examinations. Since then, bone changes in scurvy have been studied in great detail, particularly by

[1] Mellanby, M. "The Rôle of Nutrition as a Factor in Resistance to Dental Caries." *British Dental Journal*, March 1, 1937.

Dr. Edwards A. Park [1] of the Johns Hopkins University. Rickets is a disease of the entire bone; scurvy affects the growing ends. In rickets, the bone tends to bend; in scurvy, to break. The ribs show beading at their junction with the breast bone exteriorly resembling rickets. The disturbance of growth renders the junction weak and nature tries to compensate by broadening the opposing surfaces of the junction. The cartilage cells continue to grow at the end of the shafts until severe scurvy develops, but the activity of the bone-forming cells is arrested and there is no increase in thickness of the bone. Furthermore, the bone already formed begins to grow thin as the cells can no longer hold the mineral salts. The regions in which these changes are greatest are the ones which in health are the site of most active development. The middle ribs become especially fragile at their anterior ends because of their exceedingly rapid growth and, under strain, give way. Also factors of strain which in health stimulate growth of new bone hasten the destructive process in scurvy.

One of the most characteristic changes is the occurrence of hemorrhages at various points in the bone itself, in the marrow or under the periosteum. Subperiosteal hemorrhages develop only when the involvement of the bone has reached an advanced stage. They originate at the ends of the bone and extend towards the middle. When the bone begins to give way, and fractures occur, the periosteal blood vessels are torn and the blood escapes under sufficient pressure to loosen the periosteum, which is more easily detached in scurvy than in health.

It is of interest that in the studies of the boys in Christ's Hospital in the years 1918–22, one of the results of the deprivations of the war years was the increased number of fractures, which decreased again as soon as the diet was improved. While attributed to low vitamin D and calcium, there was also an increase in the incidence of rheumatism

[1] Park, E. A., Guild, H. M., Jackson, D., and Bond, M. "The Recognition of Scurvy with Especial Reference to the Early X-ray Changes." *Archives of Diseases in Childhood,* Vol. 10, page 265 (1935).

during the same years, which fell off as sharply as the fractures when the diet was improved. Such vague pains often arise from lack of vitamin C. The increase in milk (which was probably unpasteurized) and in fruits and vegetables in the diet, would materially increase the vitamin C content of the diet and perhaps best explain the decline in fractures and rheumatism.

Changes in the Blood Vessels

The hemorrhages which are so characteristic of scurvy are due to the failure of the intercellular cement substance in the walls of the blood vessels, so that the capillaries become very fragile and rupture under strains which would ordinarily have no such effect. Since the changes in the capillaries are one of the earliest to occur in vitamin C deficiency, a great deal of attention has been given to their study in the hope of getting a test for subacute scurvy. Göthlin, of the University of Upsala, Sweden, applied a compression band to the arm above the elbow so that bending of the elbow brought about increased intravascular pressure in the skin. If the capillaries were weak, tiny hemorrhages appeared with very low increases in pressure. Göthlin tested 50 children, 11 to 14 years of age, from the school of Upsala and two nearby country districts in the spring and among these found eleven with an especially low capillary resistance. Of these, ten were given an orange daily for 3 to 5 weeks and this treatment brought the capillary strength of nine of them up to that of healthy university students tested in September. The tenth became worse, and the failure of vitamin C to cause improvement showed that some other cause was operating here. The most deficient of all was a twelve-year-old country girl who had the typical gums of scurvy, spongy, swollen, and red. Some of her teeth were also slightly loose. Her recovery is thus described. "I shall never forget how this little girl with the dull, tired, resigned expression of face, through five weeks intensive treatment with orange juice awakened, so to speak, how

her movements became livelier and her eyes grew bright, and how her looks showed what pleasure she got out of life." [1]

Another method of applying the capillary resistance test is by using a suction cup placed over the skin, the withdrawal of air by means of a vacuum pump creating a negative pressure. Tests in this way were made by Dalldorf [2] at the Grasslands Hospital, Valhalla, New York, on a group of 52 children who came to the hospital from very poor homes but not suffering from any disease known to cause capillary fragility. Judged by their capillary resistance, the incidence of subacute scurvy was between 35 and 66 per cent. At the end of two months on a diet rich in vitamin C, the resistance of the group as a whole had definitely increased.

This test is not of universal application as a means of detecting suboptimal intakes of vitamin C because individuals differ very greatly in capillary resistance. It has furnished, however, very convincing evidence that vitamin C will improve the strength of the blood vessel walls when weakness is due to deficiency of this substance in the diet.

Resistance to Infection

The control which the various hormones exert in nutrition is strikingly specific. Insulin from the pancreas is concerned with carbohydrate metabolism, parathormone from the parathyroid with the calcium metabolism, thyroxin from the thyroid with the energy metabolism. The control exercised by the vitamins which, like hormones, are effective in exceedingly small quantities, cannot at the present time be described so exactly. The nearest approach is perhaps the newly discovered relationship of vitamin A to the health of epithelial cells and vitamin B to the oxidation of carbo-

[1] Göthlin, G. F. "A Method of Establishing the Vitamin C Standard and Requirements of Physically Healthy Individuals by Testing the Strength of Their Cutaneous Capillaries." *Skandinaviches Archiv für Physiologie*, Vol. 61, page 225 (1931).

[2] Dalldorf, G. "Test for Subclinical Scurvy in Man." *American Journal of Diseases of Children*, Vol. 46, page 794 (1933).

hydrates, and especially of pyruvic acid, in the brain. Vitamin C is concerned in some way with factors which hold cells together in specialized tissues and organs, and its withdrawal means widespread disintegration. As has been already shown, the walls of the blood vessels, the marrow and the calcified portions of the bones, the connective tissue wherever found, even the nerves, are involved in the general collapse. Teeth are loosened from their sockets, their roots absorbed; the walls of the lungs cave in, owing to dissolution of connective tissue; the capillary walls give way and blood stagnates in minute pools, making slight hemorrhagic spots called petechiæ. The bones lose their calcium because the connective tissue is unable to hold it, and symptoms similar to rickets are observed.

It would be strange if under such circumstances bacteria of many sorts did not find ready access to organs and tissues and aid in their deterioration. Hess called attention to the fact that in infants one of the striking and important symptoms of scurvy is susceptibility to infection. In the earlier investigations of the effects of scurvy on guinea pigs, animals which had been fed adequate amounts of antiscorbutic food were found to be less susceptible to inoculations with certain organisms of low virulence obtained from the tissues of other guinea pigs affected with scurvy, than poorly fed animals. More recently latent scurvy has been induced in guinea pigs by means of a diet of oats, bran, and milk freed from vitamin C by heating plus a very small amount of orange juice (2 cc.) every third day, and the animals' resistance to infection has been tested by dosage with various microorganisms. Inoculation with 1,000 million pneumococci was fatal to all those with the limited vitamin C intake, while those with a liberal supply were quite resistant. Experiments with three other common types of bacteria gave similar results, showing how important a liberal supply of this vitamin is for full protection.

Several tests of the power of guinea pigs to resist the tubercle bacillus agree that in the scorbutic animal tubercu-

losis develops more rapidly than in the nonscorbutic. These studies have aroused interest in the relation of vitamin C to human tuberculosis and some recent observations of vitamin C intake and outgo in this disease indicate an increased requirement.

Increased resistance to a bacterial toxin due to vitamin C has been demonstrated by King and Menten [1] who gave guinea pigs two different dosages and then injected diphtheria toxin four times within 29 days. Before there were any signs of scurvy, animals on the lower vitamin C intake averaged three times as much loss in weight. It was further found that in addition to greater injury to the tissues, the toxin caused a definite loss of vitamin C from the adrenals, pancreas, kidneys, and liver. This is in harmony with an experience of Dry in Africa, who as Medical Officer of the Rhodesian Railway had to deal with an outbreak of scurvy among the native laborers. They had been fed a diet according to government regulations, which included all the essentials of an adequate diet, but the natives were beset with intestinal parasites and could not utilize the vitamin when taken by mouth. The only successful mode of treatment was to inject orange or lemon juice directly into the blood stream.

Measurement

The guinea pig has proven a most useful means of making quantitative comparisons of the vitamin C content of different foods, since none of the other common laboratory animals develop scurvy. Two methods of making the tests have been proposed; namely, Höjer's, in which disturbance of the tooth is taken as the first sign of scurvy, and the feeding method, perfected by Sherman, La Mer, and Campbell, in which feeding is conducted through a 90-day period (if the animals live so long) and then post-mortem examina-

[1] Menten M. L., and King C. G. "The Influence of Vitamin C Level upon Resistance to Diphtheria Toxin. II. Production of Diffuse Hyperplastic Arteriosclerosis and Degeneration in Various Organs." *Journal of Nutrition,* Vol. 10, page 141 (1935).

tions are made for such signs of scurvy as hemorrhages into ribs, joints, muscles, and intestines; and fragility of the bones, as tested in the jaws, teeth, ribs, and joints. The amount required for the tooth tests has been found to be

(*Courtesy of Dr. H. Goss*)

Fig. 80.—A Guinea Pig Being Fed a Measured Amount of Orange Juice to Test Its Vitamin C Value.

approximately twice that required for protection against any other signs of scurvy.

Young healthy animals, weighing 250 to 300 grams, are fed a standard vitamin C free diet, adequate in all other respects, to which measured amounts of the food to be tested are added. Under carefully controlled conditions the smallest dosage which will permit normal growth and prevent the appearance of any sign of scurvy for 90 days is taken as the standard unit. Measurements of foods in shares based on this unit are given in Table I of the Appendix.

By the researches of several laboratories, it has been shown that for a guinea pig the minimum protective dose of pure crystalline vitamin C (ascorbic acid) is between 0.75 and 0.5 milligram per day. The minimum protective dose of

orange or lemon juice has been found to be about 1.5 cc. per day; 1 cc. of orange juice has been reported to yield 0.5 milligram of ascorbic acid.

With the discovery of methods of synthesizing vitamin C cheaply, the possibilities for quantitative research have been greatly increased, and the development of a chemical test as well as a biological one has been the objective of active research. It had been noted as early as 1932 that an organic dye which gives a pink color in a suitable medium was promptly decolorized by addition of a solution containing vitamin C, and much effort has been expended in perfecting this so called "indophenol" test for use with foods and other biological materials. Not all of the difficulties have been overcome as yet, but for many purposes it now offers a much more rapid means of assay than feeding tests with guinea pigs. This test has been especially welcomed as a means of measuring the excretion of vitamin C in the urine. Another colorimetric test of interest is that in which an enzyme, present in the squash, capable of oxidizing the vitamin has been used. Since vitamin C exists in several forms and since other substances may be present which interfere with getting the true vitamin C value, it is still necessary to check results of chemical tests with those found by guinea pig feeding.

An international unit has been adopted for vitamin C which is 0.05 mg. of pure crystalline ascorbic acid. This amount is usually found in 0.1 cc. of lemon juice. The Sherman guinea pig unit is equivalent to 10 international units.

Sources

Vitamin C is produced by the plant in the process of its growth. It is not present in dry mature seeds, but develops as soon as they begin to sprout. It is found in all growing parts of plants, but is most abundant in actively functioning and succulent fresh green leaves where, as Szent-Györgyi has shown, it is essential for the respiration of the plant. It is also found in juicy stems, tubers, bulbs, roots, and fruits

among which the citrus fruits and the tomato are outstanding. Old-time remedies for scurvy, such as fir tops, pine needles, water and garden cresses, juices of scurvy grass, nettles, burdock, dandelions, field daisies, and turnips as well as of oranges and lemons, attest the wide range of vegetable sources discovered by man in the past. It must be noted, however, that many decoctions were boiled so long that it is probable that they owed their chief value to the orange or lemon juice which was frequently added. A preparation made by pounding oranges to a pulp, rind and all, unwittingly took advantage of the vitamin C in the rind as well as in the juice. The signal difference between the period before the discovery of vitamin C and after is that now we know more precisely what we seek and how to conserve it. An old writer, who commends lemon juice as "a precious remedy and well tried," also suggests that when lemon or orange juice cannot be obtained "nitre dissolved in vinegar" or water acidulated with nitric acid may be substituted. Today we know that it would be futile to place hope in the latter. We have substituted scientific knowledge for tradition.

As a general preventive of scurvy in the temperate zones in the past the potato undoubtedly has held first place. Hess wrote in 1921: "It is hardly an exaggeration to state that in the temperate zones the development or nondevelopment of scurvy depends largely on the potato crop. In Ireland, when the potato has failed, scurvy has developed. The same thing has been true in Norway. To a minor degree this happened in 1914 in various localities in the United States when the potato crop was inadequate. This is attributable in part to the fact that the potato is an excellent antiscorbutic, but to a greater extent because it is consumed during the winter in amounts that exceed the combined total of all other vegetables."

Scientific investigation has shown that vitamin C is very irregularly distributed in food materials and also very easily destroyed. It is necessary to know the conditions under

which a food has been secured, the processes to which it has been subjected in preparation for the table, as well as its original store of the vitamin, to determine its practical value as an antiscorbutic. Fresh raw cabbage contains more vitamin C than fresh raw potato, but there is little loss in cooking the potato whereas the cabbage very rapidly loses its antiscorbutic value when heated and, when dried at temperatures well below the boiling point, it still loses the vitamin more or less completely, according to the length of time allowed for drying and the temperature maintained during the process.

Apples vary greatly with variety, the richest American variety so far studied being the Baldwin with 112 units per pound and the poorest the Delicious with 18 units per pound. Storage results in considerable loss, most of the vitamin having disappeared after 9 months in an ordinary cellar, and about one fourth after 6 months in cold storage. The skin contains a considerable store of the vitamin, so that values for the flesh are lower than for the unpared fruit. The values in this book are for the fruit after paring. Cooking destroys much of what is present in the raw flesh, so that apple sauce is not an antiscorbutic, as a man found to his sorrow who undertook to live on milk, whole grain cereals, and apple sauce when in financial straits, and after a time became a patient in a hospital and diagnosed as a case of scurvy. Raw apples, eaten skin and all, in generous quantities, have undoubtedly provided protection in many a country home in the days before the cause of scurvy was so well understood, and before oranges and tomatoes were so readily available as protective foods.

Animal foods are less satisfactory sources of vitamin C than vegetable foods. Eggs have none and what little there may be in fresh raw muscle becomes practically negligible in meat as ordinarily eaten. Even in liver, which is normally well supplied with vitamins A and B, vitamin C is found in low concentration and is lost in cooking. The amount in fresh raw milk depends upon the diet of the cow, but in

practice varies less with the season than generally supposed, probably because of the present custom of feeding milch cows either ensilage or roots in winter. When the cow is in pasture eating fresh green grass there may be from three to five times as much as after months on dry feed. The care of fresh milk is also a factor, since a bottle of milk standing in the sun for half an hour loses most of its vitamin C. This makes it evident that a nursing mother cannot transmit to her offspring an ideal amount of this vitamin unless her own diet affords a liberal supply.

When milk is heated to destroy microörganisms the amount of vitamin C lost will depend upon the conditions under which the heating is conducted. Milk brought rapidly to the boiling point, held there two minutes, and quickly cooled, loses less than that pasteurized for 20 minutes at 165° F. Milk pasteurized in presence of copper will lose vitamin C because the copper changes it to an active form. Milk dried rapidly at a moderate temperature retains most of its original antiscorbutic value. Since vitamin C is so important for the welfare of the infant, and since for sanitary reasons sale of fresh raw milk in cities is seldom practicable for a large part of the population, it is becoming a routine practice to give all infants some food of high antiscorbutic value, such as orange or tomato juice, instead of trying to depend upon milk for this vitamin. Human milk has been found to be five or six times as rich as cows' milk.

Heating, drying, and aging have all been shown to be factors in the destruction of vitamin C, but operating differently with different foods, and demanding consideration of time, temperature, and other factors contributing to oxidation. Unless one has specific knowledge of the vitamin C content of foods generally it is best to establish a habit of eating regularly some food or foods of high antiscorbutic value. The regular consumption of not less than four tablespoonfuls of orange or eight of tomato juice in the daily diet is a protective measure of great value, even when potatoes and other fruits and vegetables are included, and

almost imperative when food shortage or economic stress forces dependence on milk and cereals for most of the ration.

Fig. 81.—Foods Yielding about 30 Units of Vitamin C.

	Grams		Grams
Apples, raw	400	Tangerine	68
Peas	75	Banana	274
Cabbage, raw	55	Strawberries	63
Lemon juice	46	Grapefruit	61
Orange juice	46	Tomato	86
Onion, raw	200	Pepper, green	15

For the full conservation of our food resources, it is necessary that certain amounts be canned or dried. Some kinds, as milk, orange juice, and lemon juice, have been commercially desiccated with little if any loss of antiscorbutic value; others, as most of our common dried fruits,

unless dried with sulfur dioxide, cannot be counted as sources of vitamin C. Vegetables are likely to lose less in commercial canning than in ordinary home cooking. Fresh market vegetables may lose as much as half their vitamin C by the time they reach the city consumer, 24 to 48 hours after gathering. Hence canning, although it may destroy some, may still conserve enough to offset the effect of aging on the fresh material. One of the advantages of a home garden lies in the possibility of using the vegetables as soon as they are gathered.

Vegetables preserved by commercial quick freezing lose practically no vitamin C while in the frozen state, but are subject to the same losses between picking and freezing and will also lose their vitamin C quickly when they are thawed, so they too, should be cooked before they are entirely thawed out.

Cooking makes available many foods that otherwise would not be practical, and often enables us to eat larger quantities of vegetables than would otherwise be possible. For the conservation of vitamin C the cooking of vegetables should be done as quickly as possible, and the juices retained whenever feasible. It must be borne in mind that a relatively high loss in cooking may be only partly offset by the larger quantity eaten when the food material is cooked. Our knowledge of the exact quantity of vitamin C in different food materials is increasing rapidly and results of recent analyses will be found in Table I of the Appendix.

Requirement

A young guinea pig deprived of all vitamin C will die of scurvy in about four weeks. A monkey will endure such deprivation from eight to ten weeks and a man from four to eight months. Holst and Frölich cite the case of a man in Oslo who tried to maintain himself on bread and water only. During the self-imposed abstinence from other food he backslid only twice, once for a pound of sugar and once for a bottle of beer. These did not add vitamin C and after seven and

one half months definite signs of scurvy in the form of hemorrhages in the legs were observed.

To protect a young guinea pig a daily dose of 1.5 cc. of orange juice is needed (about 0.5 mg. pure vitamin C) while twice as much is required to prevent degeneration of the teeth. For a monkey weighing two or three kilograms, the minimum protective dose has been found to be about the same amount required for a guinea pig weighing 300 to 400 grams; this means about 0.5 cc. of fresh orange juice per kilogram of body weight.

Göthlin, who found that the strength of the capillaries of Swedish school children could be increased when low by the regular administration of orange juice for a few weeks, has sought to use the capillary resistance test to learn the vitamin C requirements of adults. He was able to study two patients in a hospital for the insane who were being fed by means of a stomach tube. Their regular diet consisted of 2 liters (a little over 2 quarts) of fresh milk, 4 to 6 raw eggs, 2 tablespoons of sugar, a pinch of salt, and the juice of one half lemon. To give these subjects a diet lacking vitamin C, that present in the milk was largely destroyed by heating, and the lemon juice was withdrawn entirely. To this basal diet, practically vitamin C free, fresh orange juice was added in measured amounts, beginning with a very small dosage and every two weeks a capillary test was given. When the number of hemorrhages increased above normal (thus giving warning of impending scurvy), the dose was increased, until finally an amount was found which gave full protection. In the case of the man this was about 0.7 cc. of orange juice per kilogram of body weight and in case of the woman about 1 cc. per kilogram. On this basis an average man would require from one and one half to two ounces per day, yielding from 20 to 30 units of vitamin C. Later, taking the amount necessary to protect the teeth of guinea pigs into account, he recommended allowances of 40 to 60 units per day for a man weighing 70 kilograms.

In the British navy one ounce of lemon juice per day eradi-

cated scurvy. There is a strong probability that the lemon juice did not always furnish the only vitamin C in the diet, but it may, perhaps, be regarded as close to the minimum protective dose against acute scurvy. All experience would indicate that for full protection against latent scurvy, at least twice as much, corresponding fairly closely with Göthlin's findings, would be advisable.

Hanke believes that the teeth and gums can be greatly improved by an intake of orange juice yielding about ten times the minimum protective dose (the juice of one half lemon in one half pint of orange juice). It seems probable that this either represents a curative rather than protective dose, the amount needed to effect cures being usually very much greater than that needed for protection, or that some other factor present in smaller amounts than vitamin C in orange juice is also valuable for tooth health.

According to the report of the British Medical Research Council [1] on the vitamins, scurvy is more rapidly contracted by men engaged in hard manual labor than by those receiving the same diet but not so active. The following case is noted: "In the expedition of the 'Alert' and the 'Discovery' to seek the North Pole in 1875 the men wintered on the ships within the Arctic circle. There was no definite scurvy diagnosed during this period, although the diet was defective from the point of view of antiscorbutic substances, notably by the substitution of lime juice for lemon juice. In the spring of 1876 the sledging parties set out, and with the performance of hard manual labour scurvy at once made its appearance, the first case occurring within ten days of departure. At first the officers escaped, but, as the men fell sick and the labour of dragging the sledges devolved more and more upon the officers, they also fell victims to the disease. In due course scurvy also broke out among the crews left behind upon the ships during the spring and summer of 1876, but its onset was distinctly later." This is an additional reason

[1] Medical Research Council. *Vitamins: A Survey of Present Knowledge,* page 268. His Majesty's Stationery Office, London (1932).

for a liberal dietary standard and for one expressed in terms of the energy requirement. It seems desirable to allow for a normal adult at least two Sherman units of vitamin C per 100 calories.

It has been found that half an ounce of orange juice yielding 7 units of vitamin C will just protect an infant from scurvy, but a modern dietary standard must provide for the maintenance of the tissues in the best possible condition, for growth at an excellent rate, and for the possibility of considerable loss of the vitamin or failure to utilize it effectively during and after even minor infections. The problem of the present is to find out just how many times the minimum will give the best results. Tests of the amount of vitamin C excreted in the urine are being used to throw light on this problem. An infant suffering from scurvy or with a history of under feeding of vitamin C will excrete less of the vitamin in the urine than a well fed infant of the same age when tested on control diets low in vitamin C. Also an infant deficient in vitamin C will excrete less when given a single large dose than a well fed infant whose tissues are presumably so well stocked that none of the incoming supply can be taken up by them. Not enough work has been done to permit us to draw any conclusions as to the most favorable intakes for different ages, and we still have to rely on dietary studies of children who have been under supervision for long periods for guidance. In the long study of nursery school children made by Rose and Borgeson, it was possible to make a test of the effect of adding a half ounce of orange juice daily to a diet which was already supplying not less than 30 units of vitamin C per day, and averaging for the whole group about 72 units daily. After the children had been under daily supervision for 12 to 15 months, one half were put on the orange juice and the other half were kept on the usual diet as controls, each child in the one group being matched as nearly as possible with one in the other group. Comparisons were made as to changes in the hemoglobin values of the blood, the effect on appetite, on the in-

cidence and duration of colds and on the rate of growth. Each child's growth record for the six months was compared with the same period of the previous year and with the six months immediately preceding the period of orange feeding. There was no evidence that the added orange juice made any difference, and it was concluded that the diet was not lacking in sufficient vitamin C for good growth. The increasing use of fruit juices rich in vitamin C improves the diet in other respects, so that it is difficult to know just how much of any benefit is to be attributed to the vitamin C. In the study of the Caries Research Committee of the School of Oral Surgery of Columbia University already referred to (page 240) the per cent of increase in caries appeared to be no higher when the diet furnished 20 units of vitamin C than when it furnished 117 to 173 units to children living in the same institution. Tests with pure vitamin C will be necessary to solve the problem of requirement, but it seems safe to suggest that an allowance of 80 Sherman units of vitamin C daily will provide a good margin of safety for children up to 10 years of age and that 60 units will do so for boys and girls over ten years old unless their energy expenditure is over 3,000 calories, when perhaps some additional allowance should be made. There is no evidence that a large amount of vitamin C does any harm and liberal amounts are to be regarded as good "health insurance."

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CHAPTER XIII

VITAMIN D AS A REGULATOR OF BODY PROCESSES

Discovery

Rickets and Cod Liver Oil

The discovery of vitamin D, like that of vitamins A, B, and C, came about partly through practical experience with a baffling nutritional disease and partly through researches on the effect of planned experimental rations upon laboratory animals. Learning how to control xerophthalmia, beriberi, and scurvy excited fresh interest in another disease in some way connected with diet but having a peculiar geographic distribution—rickets, the commonest nutritional disease of children in the temperate zone.

It is thought that rickets first appeared as a menacing disease in the great towns in the low countries of northern Europe, although it probably existed in England before the days of the Romans. Its prevalence in severe form in the British Isles led to its being called early in the seventeenth century the "English Disease." The first English treatise on the subject was written in Latin and published as a thesis for the degree of Doctor of Medicine at Leyden in 1645 by Daniel Whistler under the title "Inaugural Medical Disputation on the Disease of English Children Which Is Popularly Termed the Rickets," but the great classic on the subject appeared in 1650, also written in Latin by an English physician of great distinction who was for over 30 years "Professor of Physic" at Cambridge, Sir Francis Glisson.

For two centuries after Glisson its cause remained a mystery, and as it is a disease which does not cause death but only makes life miserable, it did not excite much interest in times when many other miseries abounded. It was rec-

ognized as a disease of the bones, in which, as one writer quaintly said, "The head waxeth too great, whilst the legs and lower parts wain too little." The state of knowledge even in the latter part of the nineteenth century was empirical rather than scientific as will be indicated in the following excerpt from an old household guide, "information for everybody," bearing the date of 1874.

"As the cause of this disease is an absence of the mineral salts, the natural remedy for the case would seem to be to give the system those salts of which it stands in need, namely, the phosphates of lime and soda. The cure, however, cannot always be effected by these means alone, though given in constantly repeated doses; the restoration to health can only be attained by a steady and gradual system of dietetics and regimen. The first indispensable requisite is change of air, and if possible, to the seaside; . . . and abundance of milk, and a full, rich diet—animal and vegetable—with fruit; the patient in this instance being enjoined to eat the rind or skin as well as the fruit, and when the digestion is good, water-cresses, radishes, salad, and any crude vegetable in which the mineral salts are in their natural abundance. . . . Though the diet and regimen are the chief agents required in the treatment of rickets, some medicine is necessary, and of that we shall now proceed to speak. In the first place, cod liver oil, on account of the nitrogen or animalizing principle it contains, has been greatly recommended in this disease, and there can be no doubt that in cases of much debility it may be given with very great effect."

Apparently little heed was paid to cod liver oil as a specific for rickets for another quarter of a century. In 1909, Dr. J. A. Schabad of the Children's Hospital in Petrograd took a four-year-old child which had been rachitic since it was a year and a half old, unable to stand or walk, and administered cod liver oil with the result that in a few days calcium and phosphorus retention increased remarkably and in two months the child was normal. Up to this time it had been customary to give phosphorus with the cod liver oil, and

any good effects had been attributed to the phosphorus, but this and other experiments of Schabad made it clear that the oil itself was responsible.

In 1917 new interest was aroused in cod liver oil therapy in this country by Hess and Unger who noted the very high incidence of rickets among negro babies in the Columbus Hill district of New York City and sought to test the efficacy of cod liver oil as a preventive measure. Over 90 per cent of the colored babies had the disease, the infant mortality rate was the highest in the city, and respiratory diseases, to which rickets is a predisposing cause, played a large rôle in the death reports. From December to June, cod liver oil was given to about 50 babies between the ages of four months and one year, frequent visits being made to the families for periodic physical examinations and to see that the oil was being taken. Infants under six months were given one half teaspoonful of oil three times a day and older infants twice this amount. Of 32 children who received the oil for six months all but two were fully protected; of 12 who received it for only four months, five were found to show symptoms of rickets; and 16 who received none were all rachitic. It is interesting to note that the report of this work "gradually spread throughout the district, and the ordinary symptoms of rickets became the common knowledge of the mothers, who often brought their babies to the consultation with the request that cod liver oil be administered"; and shortly afterward the New York City Department of Health established a rickets clinic in connection with its baby welfare station, where cod liver oil could be dispensed at cost.

Further interest in rickets was stimulated by the acute outbreak of nutritional disorders of bones not only in children but also in adults in Germany, Austria, and Poland at the close of the World War. In Vienna the disease was particularly bad, and this city became the seat of the investigations of Dalyell and Chick sent by the Lister Institute of London to study the situation. They began investigations in the autumn of 1919, at one of the principal medical centers

of the Health Insurance Organization of Vienna. Between January and May (1920) over six hundred applied for help, of whom about one third were chosen for special study. Most of the cases were middle aged or elderly people who had been living on a diet restricted to bread and vegetables mainly, with small amounts of flour and sugar—no milk, meat, eggs, butter, or other fat. Their disease corresponded closely in character with rickets, which was also so widely prevalent that every child in central Europe was said to have been rickety at that time. In rickets there is a failure to deposit calcium and phosphorus in the growing bone. In the corresponding disease of adults, called osteomalacia, the bones soften as the calcium and phosphorus already deposited there are withdrawn and excreted. The first symptom of the disease is difficulty in walking and a peculiar shuffling, waddling gait; as it progresses movements become more difficult and the hands and arms are used as much as possible to save the lower part of the body. To effect a cure various additions to the diet were tried. Increasing the total calories with cereals and sugar had no effect on the bone disease, nor were about a pound and a half of green vegetables of advantage in this respect though they caused some increase in weight. But cod liver oil effected a speedy cure, when 30 to 40 grams (2½ to 3 tablespoons) were given daily. There was great inprovement within a week, in 12 days a very much crippled patient moved with ease and in 18 days could "spring from bed without use of the hands."

Experimental Rickets

Among the confusing observations in regard to the etiology of rickets one of the most puzzling was that the apparently well fed child often fell a victim to the disease and that cutting down the amount of his food might bring about improvement. In 1908, Dr. Leonard Findlay, at the University of Glasgow, produced rickets in a group of puppies in laboratory cages on a milk and porridge diet. Inasmuch as another group allowed to run in the open did not contract

rickets, he thought that muscular exercise was the explanation of the difference. In 1917, McCollum and Simmonds, studying the dietary deficiencies of the cereal grains, observed that many rats developed beaded ribs and other skeletal deformities, and they tried all sorts of changes in the mineral content of their rations to prevent these abnormalities of the skeleton which so strongly suggested rickets. They were convinced that the cause lay in the diet. They

(Courtesy of Professors H. Steenbock and E. B. Hart)

Fig. 82.—A Rachitic Puppy.

said that the diet was the sole determining factor in the etiology of the lesions in question, for the entire colony of approximately 2,000 animals lived under identical conditions except for those related to the composition and source of their food.

While these observations were being made in Baltimore, Dr. E. Mellanby in a research conducted for the Medical Research Council of Great Britain succeeded in inducing rickets in puppies by means of various faulty diets, such as

bread or other cereal food with a little whole milk; or bread and a little separator milk, with linseed oil to replace the milk fat. When cod liver oil was substituted for other fat in the rachitic diet, the disease was prevented; since cod liver oil was by that time (1919) known to be rich in vitamin A, Mellanby concluded that this vitamin must be antirachitic as well as growth promoting.

Inasmuch as rickets is a disease in which the bones are deficient in calcium, the very natural notion was widespread that administration of calcium should cure it. However, dosage with calcium generally gave disappointing results and rickets sometimes developed when children were fed liberally on cow's milk, rich in calcium. In 1921, Sherman and Pappenheimer threw light on this anomalous situation from another angle. They reported that rickets could be speedily induced in rats by the use of a diet lacking cod liver oil, high in calcium, and low in phosphorus; and that this rickets-producing diet could be changed to an antirachitic one by the simple addition of a suitable amount of a phosphorus salt.

A little later the Johns Hopkins investigators, having also succeeded in evolving a rickets-producing diet low in phosphorus, made the further observation that butter fat, while preventing the disease which results from shortage of vitamin A, did not satisfactorily modify the pathological condition of the skeleton; "if anything, it was intensified, probably as a result of the slight stimulation given by the butter fat to the growth of the bone."

On the other hand, when cod liver oil was added to the diet there were no signs of rickets. Within the year (1921) this difference between butter fat and cod liver oil was explained. Hopkins had pointed out in 1920 that if oxygen were allowed to pass through a heated fat any vitamin A which it contained would be destroyed, and very shortly McCollum in Baltimore, Steenbock in Madison, and Coward and Drummond in London reported that cod liver oil so treated lost its growth promoting power but retained its antirachitic property.

It was found, too, that the antirachitic substance could be separated from the fat of cod liver oil. Doctor T. F. Zucker, of the College of Physicians and Surgeons of Columbia University, in 1921 devised a method of making a preparation many times more powerful than the original cod liver oil, and free from vitamin A. This removed the last doubt that the antirachitic substance was a definite chemical entity, entirely distinct from vitamin A, and McCollum named it vitamin D.

Rickets and Sunlight

In the earlier clinical studies of rickets, two theories as to its cause were common; one that it is primarily a dietetic disorder, the other that hygienic conditions, especially lack of sunlight, overcrowding, poor ventilation, and prolonged indoor confinement of infants in the winter time are the chief contributing factors. In 1890 Dr. T. A. Palm, an English physician practicing for some years in Japan, became interested in the geographical distribution of rickets, being struck with its absence in Japan "as compared with its lamentable frequency among the poor children of the large centers of population in England and Scotland." He had read the report of a committee of the British Medical Association published in 1889, which called attention to its great frequency in large towns and thickly peopled districts where industrial pursuits are carried on and to its specially great prevalence in the industrial zone between the Firth of Clyde and Firth of Forth. In Glasgow it was almost universal, and in London the situation was not much better. Palm had also read Hirsch's *Handbook of Historical and Geographical Pathology* (1886) in which it was said of rickets, "In amount and severity of type its stands in a definite relation to climate that countries with a cold and wet climate, subject to frequent changes of weather, such as Holland, many parts of England, the north German plain, the mountainous regions of central and southern Germany, and the plains and mountainous districts of northern Italy, if they

(Courtesy of Professor E. B. Hart)

Fig. 83.—A fall-dropped calf, nursed six months by the mother, given a concentrated ration including corn, bran and linseed meal, and hay of low quality which was also fed the mother. A little out-of-doors exercise was allowed in the early morning. This animal was brought to the Wisconsin Agricultural Experiment in June, appearing as in the upper photograph. The deficiency of vitamin D was manifested by reduction in growth, by stiffness, and deformity of the bones.

The lower photograph shows the same calf six months later, after treatment with 40 cc. of oxidized cod liver oil per day as a source of vitamin D.

are not the exclusive seats of rickets are at all event its headquarters." He sent out a questionnaire to various medical missionaries in China and Thibet because he thought, "If we find the disease to be unknown where the diet and sanitary surroundings are even worse than in places where the disease prevails, we can no longer regard them as prime factors in producing the disease."

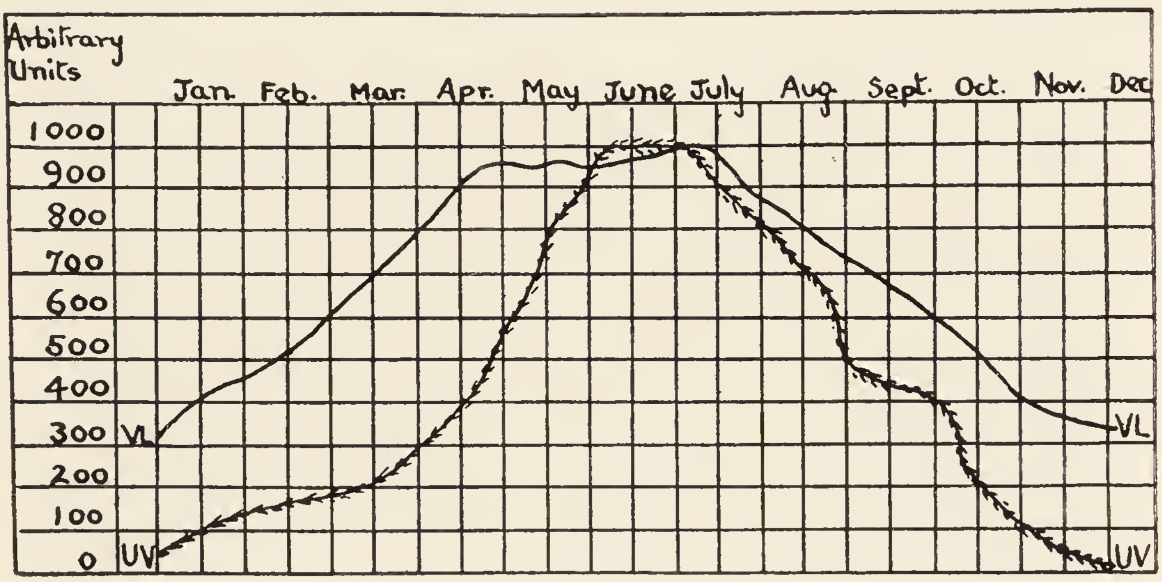
The reports, mostly from rural regions, told of poverty, of poor food, of filthy streets, and utter absence of sanitation, but no rickets. The air was generally dry and stimulating, with much sunshine, people living out of doors, the children practically naked and rarely weaned before three years of age. Palm suggested as a result of his study that "sunlight is essential to the healthy nutrition of growing animals and that a deficiency of it characterizes the localities or conditions of those who suffer from rickets and is the most important element in the aetiology of the disease."

Glasgow, where rickets is almost universal and exceptionally severe, has only 1,086 hours of sunshine annually, which is less than any other large city in the temperate zone. London is not much better off, having only 1,227 sunny hours. New York, Washington, D. C., and Chicago have about twice as much sunshine as London. It has been stated by Dick in his book on rickets (1922) that 80 per cent of the children in the London County Council schools have rickets and Plimmer suggests that the proportion of men rejected since the World War as army recruits on the ground of physical unfitness corresponds with this earlier estimate of the percentage of rickety children in London schools.

Refined methods of diagnosis were made possible by use of the X-ray and many children who would not have been classified as rachitic by the earlier clinicians were added to the list of the afflicted. Hess and Unger found that fully three fourths of the bottle fed and half the breast fed babies of New York City showed at least slight signs of rickets in March, the time of year when the disease reaches its peak. In New Haven, Dr. M. M. Eliot in a study sponsored by

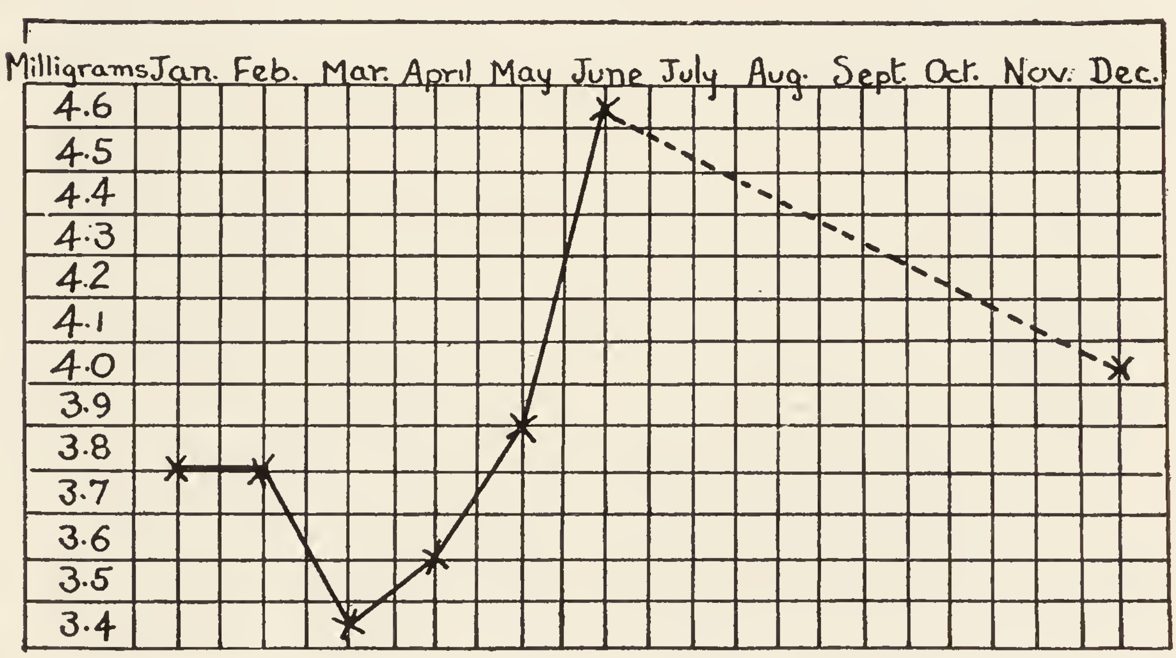
the United States Children's Bureau and the Pediatric Department of the Yale School of Medicine, found that 179 out of 216 infants examined (83 per cent) showed evidence of mild rickets by X-ray examination before 8 months of age.

In 1921 it was demonstrated by Hess, Unger, and Pappenheimer in New York and by Shipley, Park, Powers, and



(*Courtesy of Dr. A. F. Hess*)

FIG. 84.—Seasonal Variation in Visible Sunlight (VL) and in Ultra-Violet Light (UV).



(*Courtesy of Dr. A. F. Hess*)

FIG. 85.—Seasonal Variation in Blood Phosphate.

Note the correspondence between the peak of blood phosphate and the maximum of sunlight and ultra-violet light.

McCollum in Baltimore that the development of rickets in rats fed a standard rickets-producing diet could be prevented by daily exposure to direct sunlight, and Hess and Unger found further that the low inorganic phosphate characteristic

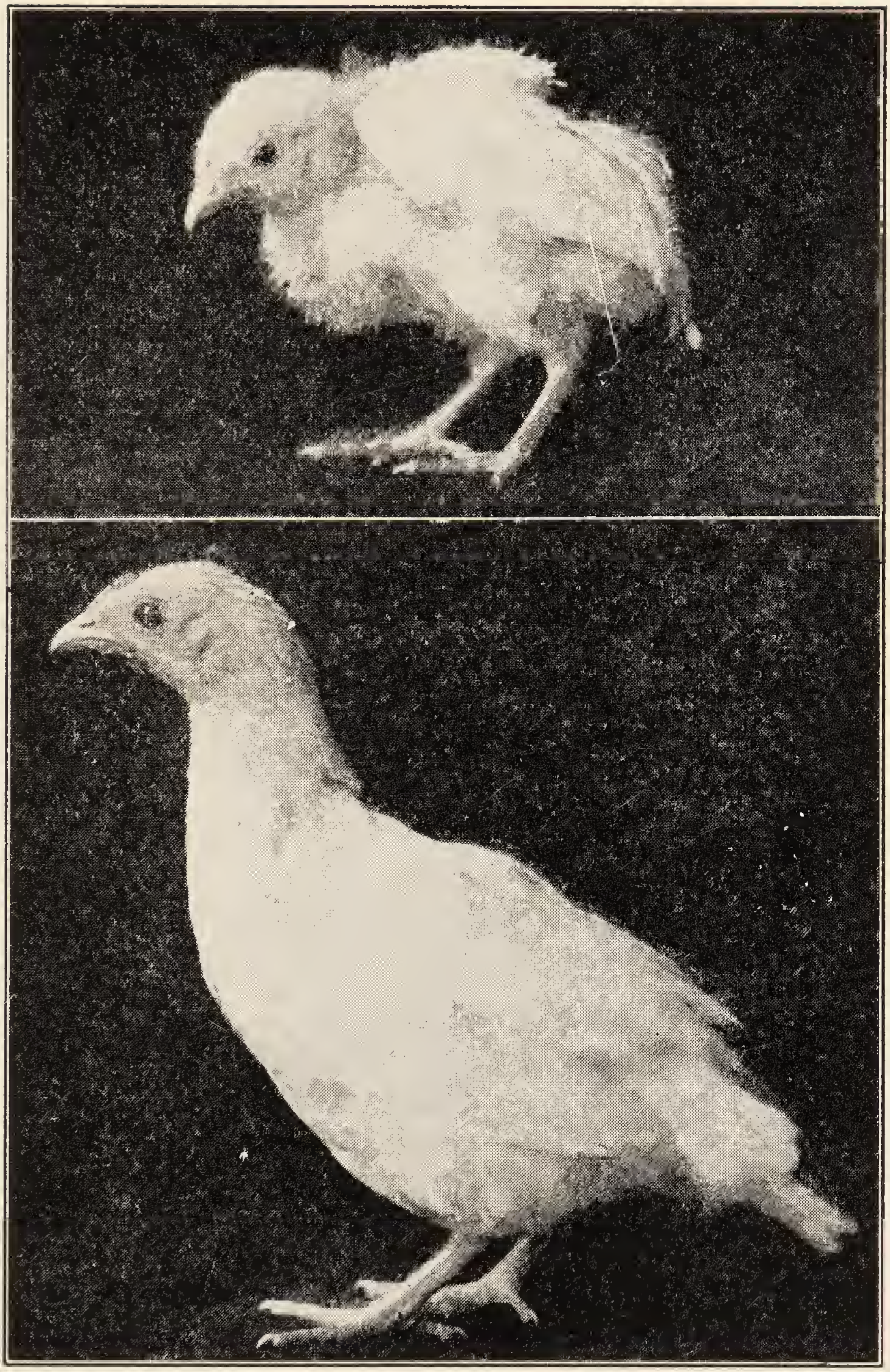
of the blood serum of rachitic infants could be raised to the normal level by daily sun baths. Thus was confirmed the strong belief of many that hygiene plays a significant rôle in rickets, and thus was explained the irregularity with which rickets occurs in the same community.

It did not take long to discover through studies on young children that there is a seasonal tide of blood phosphorus which is directly related to the amount of sunshine at different times of the year. This led to the application of "artificial sunlight" by means of a carbon arc lamp similar to that employed in taking motion pictures, and to the realization that it is the short rays known as the ultra-violet which are curative of rickets. The fact that these shorter rays do not penetrate dark clothing or a heavily pigmented skin helped to explain further some of the irregularities in the occurrence of rickets, especially the high susceptibility of negro infants.

Light and Vitamin D

How the same effect could be secured by such diverse agencies as (1) direct sunlight, (2) cod liver oil, (3) a ration carefully balanced with regard to calcium and phosphorus, and (4) ultra-violet light was a mystery. The solution was found in 1924 when almost simultaneously Hess in New York and Steenbock and Black at the University of Wisconsin showed that liver, lung, and muscle tissue from irradiated rats would promote bone calcification in rachitic rats while that from nonirradiated rachitic animals would not do so. The next step was to try irradiation of food, and it was found that cottonseed and linseed oils could thus be made antirachitic but mineral oil (which is not fat) could not, and that in general only those foods could be irradiated successfully which contain true fat.

As fast as possible, all sorts of material were irradiated and tested. The success of irradiation was found to depend not on the fat present in the food, but on another substance occurring in minute quantity in the oils of seeds including cereal grains and in vegetable oils such as olive, peanut, and



(*Courtesy of Dr. Harry Steenbock*)

Fig. 86.—These two chicks are the same age and were fed the same diet, but the upper one was kept in a dark room, while the lower had plenty of sunshine.

cottonseed, known as phytosterol; or in a closely related substance in animal fats called cholesterol.

It was now possible to produce an antirachitic substance outside the living organism; in other words to make vitamin D. But the chemical search for the pure vitamin in activated cholesterol led to a further surprise. The substance which could be most effectively activated proved to be another chemically related substance associated with cholesterol, called ergosterol, then little known and supposed to have no biological significance. It is found in largest amounts in ergot, from which it gets its name, and in yeast.

Pure ergosterol was irradiated and found to have a vitamin D activity 200,000 to 700,000 times that of cod liver oil. It is curative for rats in doses of 0.0001 milligram. The identification of ergosterol as a substance from which vitamin D can be made was announced in 1927 by Rosenheim and Webster and also by Windaus and Hess. Irradiated ergosterol was promptly made available to the public as a concentrated solution in oil known in this country as viosterol, usually prepared so as to have a potency in rat units about 250 times that of a standard cod liver oil.

Activated ergosterol was found to contain at least half a dozen substances. It was "a complex resinous mixture" resisting all efforts at crystallization. Finally in 1930 Dr. R. B. Bourdillon, with Askew and other associates at the National Institute for Medical Research in London, was able to produce small amounts of a crystalline substance which he named calciferol, protective for a rat in doses of 0.000005 milligram. Later further purification was reported and twice as great antirachitic potency. Meanwhile Windaus, who as Professor of Chemistry at the University of Göttingen had engaged in the study of cholesterol many years, was also giving his attention to the search for pure vitamin D, and in 1931 reported the isolation of two crystalline substances protective for a rat in dosage of about 0.000003 milligram, one of which was subsequently identified as the calciferol of the English investigators. The other was the same sub-

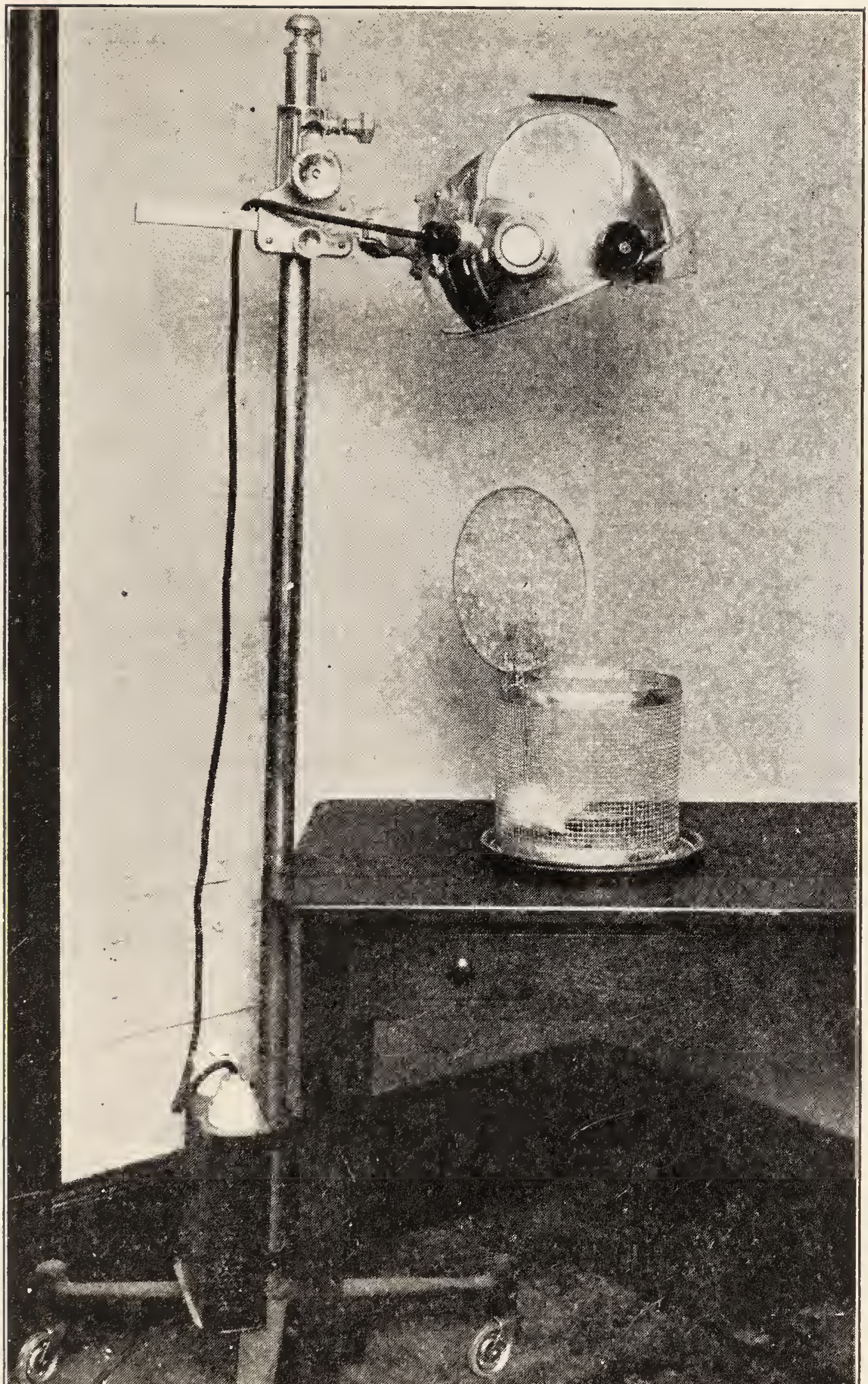


Fig. 87.—A Mercury Vapor Quartz Lamp Which Emits a Light Richer in Ultra-Violet Rays than Sunlight.

stance in combination with another which was physiologically inactive. Pure calciferol has an antirachitic potency of 40,000 international units per gram.

Further investigation revealed that not only ergosterol and cholesterol but other closely related compounds could be made antirachitic by irradiation. Tests on chicks and rats showed that a dose ample for one might be too small for the other. Hence it gradually became clear that vitamin D is not a single substance, but a group of closely related compounds. New compounds with vitamin D activity have been developed in the laboratory, so that seven forms of vitamin D are now known to the chemist. The knowledge that the chick responds better to one form while the rat responds better to some other form has raised the question of the efficiency of different forms for the human species. While the evidence is as yet rather fragmentary, the differences appear not to be large.

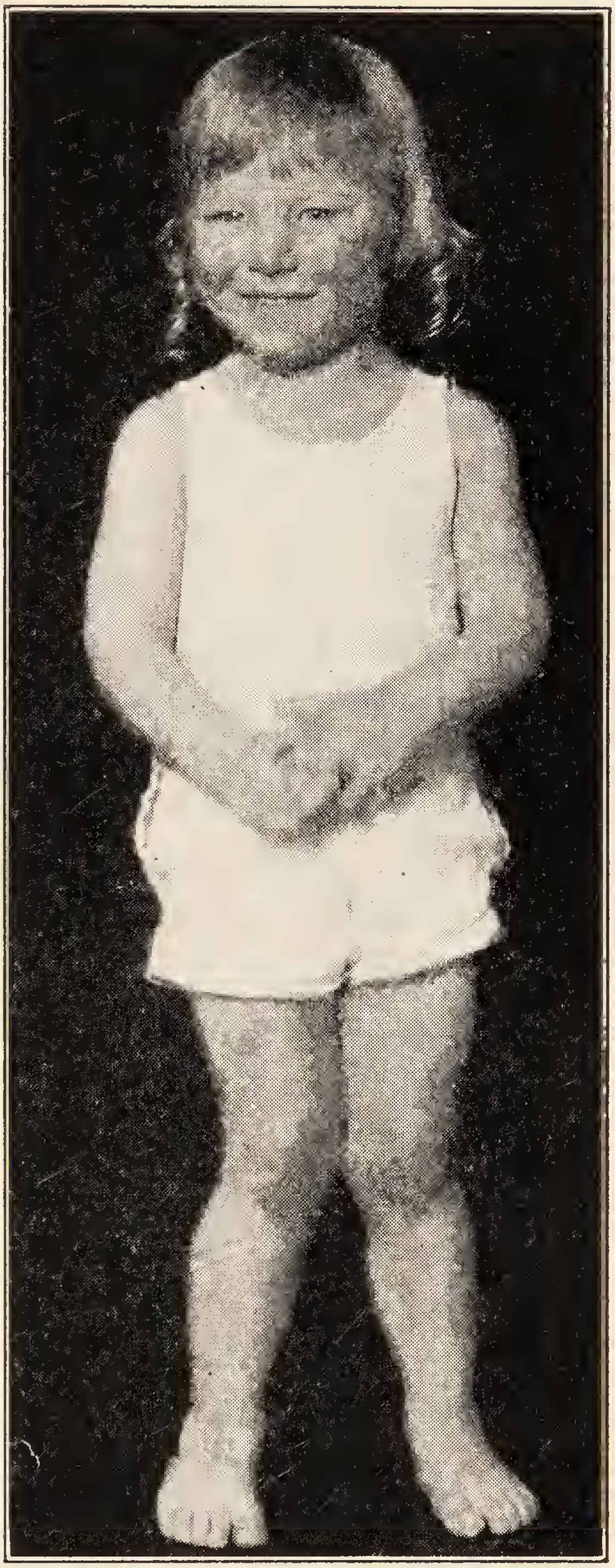
Doctor C. E. Bills, the discoverer of several forms of vitamin D, summarizes the situation thus: "If the number of species put to the test is extended, mammals will be found to respond well to either irradiated ergosterol or cod liver oil, and birds, in general will do poorly with irradiated ergosterol but will do well with cod liver oil." [1]

The Prevention and Cure of Rickets

Although rickets is a disease affecting the whole body, its most characteristic symptom is a failure of the bones to calcify properly, with resulting deformities. The first defect to appear is the so called "rachitic rosary"—a row of bead-like protuberances down each side of the chest where the bones of the ribs join the costal cartilages. The chest fails to develop normally, the ribs are thrust forward, forming a pigeon breast, and the lung space is contracted, interfering with deep full respiration. The ends of the long bones become enlarged, especially at wrists and ankles. Calcium

[1] Bills, C. E. "New Forms and Sources of Vitamin D." *Journal of the American Medical Association*, Vol. 108, page 13 (1937).

phosphate is not deposited in the normal way. The evidence of rickets is seen at the junction of the shaft of the bone with its head, called the epiphysis. In the normal bone this junction is a straight, clear line; in the rachitic bone it is ragged if not wholly obscure. The cartilage of the epiphysis is not converted into bone, but persists and increases, and there is an irregular enlargement of the soft tissue. The lace-like bony structures in the end of the shaft, called trabeculæ, are poorly developed, giving further signs of the inability of the body to store calcium and phosphorus. They are normal reservoirs of calcium and phosphorus where any surplus is stored and from which these elements are withdrawn if needed elsewhere.



(Courtesy of Dr. Ulysses C. Moore)

FIG. 88.—A Case of Mild Rickets Resulting in Knock-Knees.

A normal calcium and phosphorus metabolism depends upon many factors, especially (1) the ability of the body to absorb these minerals from the food; (2) the supply of enough of each element to meet the requirements of growth; and (3) the amount of vitamin D supplied. Since calcium and phosphorus are the materials upon which the growth and maintenance of normal bone so largely depend, it is easy to see

that calcium and phosphorus must be furnished in sufficient amounts to get the best results. In case of the rat, suitable proportions of these minerals seem to be more important than a large amount of vitamin D in avoiding rickets, but in human beings liberal vitamin D is essential to the best utilization. Normal infants on a diet of milk, even when showing no symptoms of rickets, retain more calcium and phosphorus from the food and grow better if given additional vitamin D. Thus Daniels and some of her associates at the Iowa Child Welfare Research Station found that giving vitamin D to babies on milk formulas increased the phosphorus retention to three or four times what it had been on the milk only, and calcium retention was also very markedly improved. It is very evident that in case of human beings vitamin D helps to conserve calcium and phosphorus even when both are fed in the liberal amounts and good proportion in which they occur in milk.

When adjustment cannot be made entirely by better absorption of calcium or phosphorus or both from the intestines, vitamin D may call out additional calcium from the bones. This explains how it is that vitamin D prevents or cures rickets even when diets are too poor in calcium or phosphorus or both. Doctor V. B. Appleton studying the nutrition of infants in Hawaii, where there is plenty of sunshine, found among 1,200 Japanese infants examined, only 16 cases of slight rickets, but in many children there was a tendency to poor calcification of the shafts of the ribs in the second half of the first year owing to the low calcium content of the food supplied when they begin to take other nourishment besides their mother's milk.

The best diet to prevent or cure rickets is one in which liberal calcium and phosphorus are kept in favorable relationship by a moderate but regular supply of vitamin D, either directly, through the action of the ultra-violet rays of sunlight upon the skin, enabling the body to manufacture its own; through the use of some food naturally rich in the vitamin, such as halibut or cod liver oil; or through the use of

a food which has been fortified by irradiation or by adding a vitamin D concentrate. The latter may be prepared from fish liver oil or by irradiation of ergosterol.

The Development and Health of the Teeth

It has been estimated that the temporary teeth come through the gums practically perfect in 98 per cent of children. Nevertheless, according to Dr. H. D. Cross of the Forsyth Dental Infirmary, 96 per cent of American children have defective teeth; and Dr. W. H. Leak, New York State Dental Inspector, said in 1920: "Ninety per cent of children in the first grades, not only in the slums but in aristocratic and best sections of cities, have bad teeth; one third have abscessed conditions in their mouths, and every fourth or fifth child does not have proper masticating surfaces. Of little tots in the first grades, 7 years of age, 40 per cent have the six-year molar decayed—a tooth which has not been in the mouth more than one year and yet the first molar of the permanent set, decayed." [1]

Until recently, measures for betterment of these very bad dental conditions which still exist in American children were chiefly directed to oral hygiene. But with the development of modern experimental methods in nutrition have come striking demonstrations that the teeth, like the rest of the skeletal structure, depend upon an adequate diet for their development and maintenance in health. The thought of a close connection between teeth and diet in case of human beings would have impressed itself sooner, perhaps, if the character of the teeth were not largely determined before birth and in infancy, before any teeth erupt and long before the permanent teeth appear.

It is well known that babies with rickets exhibit delayed dentition and often have teeth which are malformed, badly spaced, and subject to decay. At least highly suggestive is the finding of Cross that 96 per cent of children coming to

[1] Cited by Snyder, J. R. "The Temporary Teeth." *Journal of the American Medical Association*, Vol. 75, page 458 (1920).

this country from the southern part of Europe have sound teeth, while 96 per cent of American children have defective teeth; and even more significant that the foreigners' teeth begin to deteriorate after residence for some time in this country. It seems likely that the lessened amount of sunshine enjoyed in cities like New York and Boston, and the decrease in the amount of cheese and fresh green food may be large factors in this tooth deterioration.

The special susceptibility to caries during adolescence may be associated with the need of more liberal amounts of calcium and phosphorus for rapid growth at this period. Doctor Price, a dentist of Cleveland, Ohio, cites a very interesting case of a 16-year-old girl who left her home in Canada to enter a college in Ohio with practically perfect teeth and in the course of a year developed 22 cavities, followed by 12 more the succeeding year. Ordinary dental care afforded no check on this rapid tooth disintegration, but the administration of a concentrate of cod liver oil was quickly effective and in the next 18 months no new cavities appeared. Apparently the dietary régime of the college dining hall coupled with a cloudy fall and winter was not as effective in promoting tooth health at this period of growth as the home environment and diet had been.

Similarly the periods of pregnancy and lactation make such heavy demands upon the mother that there is much basis in fact for the old saying "a tooth for every child." For tooth protection there is certainly need for liberal supplies of calcium and phosphorus with sufficient vitamin D to insure their fullest utilization. The importance of the diet of pregnant women is thus expressed by one of the best informed and most conservative pediatricians: "Personally, I believe that if pregnant women received ample well balanced diets, in which green vegetables were abundantly supplied and cow's milk was regularly taken, and they were kept a sufficient part of their time in the open air and sun, and their infants were placed in the direct rays of the sun for a part of each day and were fed cod liver oil for the first two or three

years of life, more could be accomplished in regard to the eradication of caries of the teeth than in all other ways put together and that rickets would be abolished from the earth." [1]

Experimental Tooth Defects

The molar teeth of rats strongly resemble those of human beings, and much study has been devoted to the production by dietary means of tooth defects in these animals, since the first caries were thus produced by McCollum and Grieves in 1922, by disturbing the calcium-phosphorus balance of the diet and giving insufficient amounts of "fat soluble vitamin" (A and D). It is possible to induce caries in rats' teeth by means of a calcium free diet, but as long as vitamin D is furnished, the calcium of the skeleton is drawn upon to maintain the normal metabolism, and this reserve must be well exhausted before caries will develop. On a diet high in calcium, very low in phosphorus, and lacking vitamin D, severe rickets is quickly induced, and caries develop rapidly. In case of children, the fact that rickets and caries develop on a diet in which cow's milk is prominent, affording liberal calcium and phosphorus, indicates that shortage of vitamin D is more serious than in the case of the rat, an animal designed by nature to live in darkness.

Lady May Mellanby observed that when Sir Edward Mellanby's puppies developed rickets their teeth were seriously affected, and began an investigation of the factors controlling normal tooth development in dogs. She has found that young puppies fed diets lacking in vitamin D show delay in the eruption of the permanent teeth; the enamel is irregularly formed and poorly calcified, the surface being pitted and grooved; the jaw bones are thickened and the teeth irregularly arranged. The dentine also is irregularly calcified, and the tissue at the margin between tooth and gum is abnormal in its development.

[1] Park, E. A. "Certain Factors Causing the Deposition of Lime Salts in Bone." *Dental Cosmos*, Vol. 65, page 176 (1923).

In 1927, the Medical Research Council of Great Britain, greatly impressed by Lady Mellanby's findings on dogs, decided to support her in an investigation of the effect of vitamin D on the teeth of children. Three institutions in the neighborhood of Birmingham were chosen, caring for 835 children from two and one half to sixteen years of age. At one of them there was added to the diet 1½ ounces daily of syrup (treacle); at another, 1½ tablespoonfuls of olive oil; and at the third, the children under eight years of age each received 1 tablespoonful of cod liver oil, and those who were older, 1½ tablespoonfuls. Thorough dental examinations were made every six months for two years. At the final inspection it was found that while the actual number of carious teeth had approximately doubled at the institutions where syrup and olive oil were fed, it had increased by only one half in the third, where cod liver oil was given.

It would thus appear that in England where rickets has been rife for centuries and where the climate continues to foster the disease, lack of vitamin D is the primary cause of dental defects, but in this country, where rickets is mild, and in tropical countries where it is nonexistent, other factors must be sought to explain the widespread distribution of dental caries.

Diets low in calcium, phosphorus, and vitamin D have been shown both clinically and experimentally to be unfavorable to normal tooth development and to their health throughout life. A tooth is never inert; it is liable to lose its mineral salts at any time when conditions become unfavorable for their conservation, just as its odontoblasts, upon which its nutrition so directly depends, become disorganized when vitamin C is lacking; and as the attaching soft tissues lose their normal character and become spongy and inflamed when either vitamin A or vitamin C is deficient.

Various experiments with children's diets in relation to dental caries suggest that teeth are either very delicate indicators of deficiencies not readily detectable or that there are factors in foods affecting teeth which are still unknown.

Diets which include daily a quart of milk, an egg, an orange, a teaspoonful of cod liver oil, an ounce of butter, and two or more servings of succulent vegetables and fruits, have been found to cause definite improvement in the teeth of children supposed to have been well fed, but until further investigations shall be made, in which only one dietary factor is varied at a time, it is impossible to know the relative importance of the five factors which certainly influence tooth health; namely, calcium, phosphorus, vitamins A, C, and D; or to know whether still others are involved. For the present the best we can do is to pattern our diets on those which have stood the test of practical experience. Thus we have a new reason for emphasizing the value of a quart of milk for every child and at least a pint for every adult, an egg a day, an orange a day (or its equivalent), and liberal amounts of vegetables, especially fresh green ones.

Measurement

The measurement of vitamin D, like that of vitamins A, B, and C, is achieved by tests on laboratory animals. Rats and chicks are both used, but the standard test adopted by the United States Pharmacopeia is made with rats. It is necessary to make newly weaned animals severely rachitic rather quickly and this is accomplished by feeding them a standard rickets-producing diet high in calcium and low in phosphorus and vitamin D. The degree of rickets thus induced may be determined by analyzing one of the leg bones to see how the calcium content compares with that of a normal animal or by what is commonly called the "line test." The "line" is one of freshly deposited calcium phosphate across the head of a long bone which can be distinctly seen under the microscope when the bone is cut and suitably stained. A Steenbock rat unit of vitamin D is the amount of vitamin D which will give a clear line test in a standard rachitic rat on a vitamin D-deficient diet in from six to ten days.

A standard reference cod liver oil is distributed by the

Pharmacopeia office to laboratories testing for vitamin D. This has been checked against the international standard, which is a solution of activated ergosterol in olive oil. One international unit corresponds to 0.001 milligram of irradiated ergosterol or 0.000025 milligram of pure calciferol and one Steenbock unit is equal to 2.7 international or U. S. P. units.

Sources

Leaving out of consideration the production of vitamin D within the living body by the direct action of sunlight upon the skin, or by the action of artificial sunlight from the carbon arc lamp, or by that of the ultra-violet rays from the mercury quartz vapor lamp, this discussion will be confined to the occurrence of vitamin D in natural foods and in other food materials in which it has been produced or increased by artificial means.

Fish liver oils are the richest natural sources of this vitamin. The yield of some of them is shown in the table below:

The Amount of Vitamin D in Some Fish Liver Oils

	International Units per Gram
Bluefin tuna	40,000
Sword fish	10,000
Yellowfin tuna	10,000
Black sea-bass	5,000
Rockfish	1,400
Chinook salmon	1,300
Halibut	1,200
Boston mackerel	750
Pufferfish	570
Turbot	260
Cod	100
Haddock	10

The body oils of many fish also furnish considerable amounts, the entire body oil of the herring yielding as much per gram as cod liver oil, that of the sardine about four fifths as much. No other type of food can compare with fish liver oils as a source of vitamin D. Of foods common in the American dietary, the egg yolk is the richest, one egg yolk being equivalent to about 0.3 gram of standard cod liver oil. Eaten

regularly by children, eggs may even turn the tide against rickets if the amount of vitamin D derived from sunshine is not too small. Casparis, Shipley, and Kramer were able to demonstrate definite healing in seven colored children upon adding to a diet of cereal and milk one or two eggs daily. They comment: "It is interesting, in the light of these findings, to note that for centuries in rural England a food which must have had a very high antirachitic potency as well as a very high caloric value was universally eaten by children as well as adults. This food was known variously as 'furmity' or 'frumenty,' 'an wholesome food,' says Domini Holliday. The recipe for this food as given by Salmon was as follows: Take some new milk or cream and boil it with whole spice (nutmeg, cinnamon, clove). Then put in your wheat or pearled barley boiled very tender in several waters; when it has boiled a while, thicken it with the yolks of eggs well beaten, sweeten it with sugar, and serve it in with fine sugar on the brims of the dish." [1]

Cow's milk has naturally a low concentration of vitamin D and since it plays such an important part in the diet, the growing practice of increasing the vitamin D content provides an extra safeguard for children. This can be accomplished by direct irradiation with artificial light under suitably controlled conditions or by the addition of a standard amount of a fat free concentrate of cod liver oil; or by feeding irradiated yeast to the cow, so that her milk will be enriched thereby. Irradiated ergosterol (viosterol) has also been fed to cows with considerable success. Direct irradiation of the cow has not proven a practical means of enriching milk, although it has some effect, summer milk being richer in the vitamin than ordinary winter milk. Enrichment of milk in vitamin D need not add materially to the cost, and will insure to all using milk in liberal amounts a regular supply of vitamin D. Meanwhile cod liver oil which has stood the test of years of use remains a "safe and sure" means of

[1] Casparis, H., Shipley, P. G., and Kramer, B. "The Antirachitic Influence of Egg Yolk." *Journal of the American Medical Association*, Vol. 81, page 819 (1923).

obtaining two vitamins (A and D), favorably influencing the calcium metabolism. Most of the vitamin D in milk is present in the butter made from it, but at best butter is not rich in vitamin D. Here, again, however, the consumption of generous amounts of butter regularly does add considerably to the total vitamin D intake. The higher plants do not require and do not produce vitamin D. Only one natural plant source has been discovered. This is an alga which grows at shallow depths in the Caribbean Sea, known as the Sargassum weed. Oils of this plant have been found curative for rickets in rats.

For babies and growing children, and probably for adults, too, the regular supplementing of the ordinary diet, however rich it may be in milk, butter, and eggs, with some especially good source of vitamin D during the periods of the year when exposure to clear bright sunlight is difficult, should become a routine practice. Cod liver oil is a source which has proven successful in a great variety of circumstances, and it has the advantage of furnishing at the same time the equally desirable vitamin A. Cod and other fish liver oils can also be irradiated so that the vitamin D potency is greatly enhanced.

Irradiated ergosterol dissolved in a small amount of oil is standardized as to its vitamin D content and sold as viosterol. A few drops daily are sufficient to protect a baby against rickets, but it should be remembered that viosterol furnishes none of the vitamin A also important for the best development. It has also been found that relatively larger doses of viosterol than of cod liver oil are necessary to cure infantile rickets.

Requirement

A vast amount of experience both with human beings and laboratory animals now attests the importance of vitamin D for the prevention of rickets and other allied diseases of the bones and for the best development of the skeletal tissues including the teeth. When the Eskimos subsist on

their natural diet of fish and meat, with large supplies of fish liver and fish oils and also often of eggs, eating all parts of the animal and thus getting calcium and phosphorus, vitamin D and even vitamin C from animal sources not usually taken advantage of in the United States, they have excellent teeth and their breast fed infants do not develop rickets. But when their natural diet is diluted with white flour and sugar their health deteriorates and dental caries and rickets make their appearance. In this case their intake of all four factors is reduced.

In India and China where the sunshine furnishes plenty of ultra-violet light and exposure to it brings freedom from active rickets even on diets poor in calcium and phosphorus, the seclusion of women and girls of the higher classes and of the Mohammedan faith results in the frequent occurrence of late rickets and of the adult disease corresponding to rickets, osteomalacia.

The amount of vitamin D needed to supplement that naturally formed in the body must vary greatly with climate, season, and mode of life. There is no way at present of measuring accurately the amount of vitamin D formed in the human body by the action of ultra-violet light. There is also a great deal of variability in the vitamin D content of natural foods, especially eggs, milk, and butter, the richest common food sources of vitamin D in this country with the exception of fish liver oils. Hens in the winter lay eggs which become poorer in vitamin D as the season advances, and cows give milk poorer in this vitamin when they do not have access to green foods in sunny pastures.

Although the vitamin D requirement depends on many factors and perhaps can never be stated in the way that requirements for calcium and phosphorus or even some of the other vitamins can, practical experience with infants in this country under controlled conditions has given us knowledge of what amounts of cod liver oil are likely to be protective for most infants on otherwise adequate diets in our climate and under our living conditions.

The United States Children's Bureau recommends that all infants, beginning at the age of two or three weeks, receive daily vitamin tested cod liver oil in two doses of one half teaspoonful each and that by the end of the third month it be increased to two doses of one and one half teaspoonful each. This is in harmony with the experience of many pediatricians who have given careful study to the problem of rickets prevention.

The commercial enrichment of cow's milk with vitamin D has been subjected to testing which shows that it is possible to produce milk which will be fully protective for normal infants when a pint and a half daily is fed. The practice of supplementing milk with cod liver oil (or some other vitamin tested fish oil) is certainly desirable for the best growth, and has the advantage of furnishing much vitamin A. Where eggs can be used freely, they too will not only furnish much of each vitamin but also considerable phosphorus and even some calcium.

With such a highly concentrated preparation of vitamin D as irradiated ergosterol, there is some possibility of overdosage, although the fact that infants are not injured by 250 times the dose required for healing of rickets indicates that there is no danger if the dosage recommended by physicians is adhered to. With natural food sources of vitamin D there is no danger of overdosage and the production of foods artificially reinforced with the vitamin is being carefully controlled to insure full safeguarding of health.

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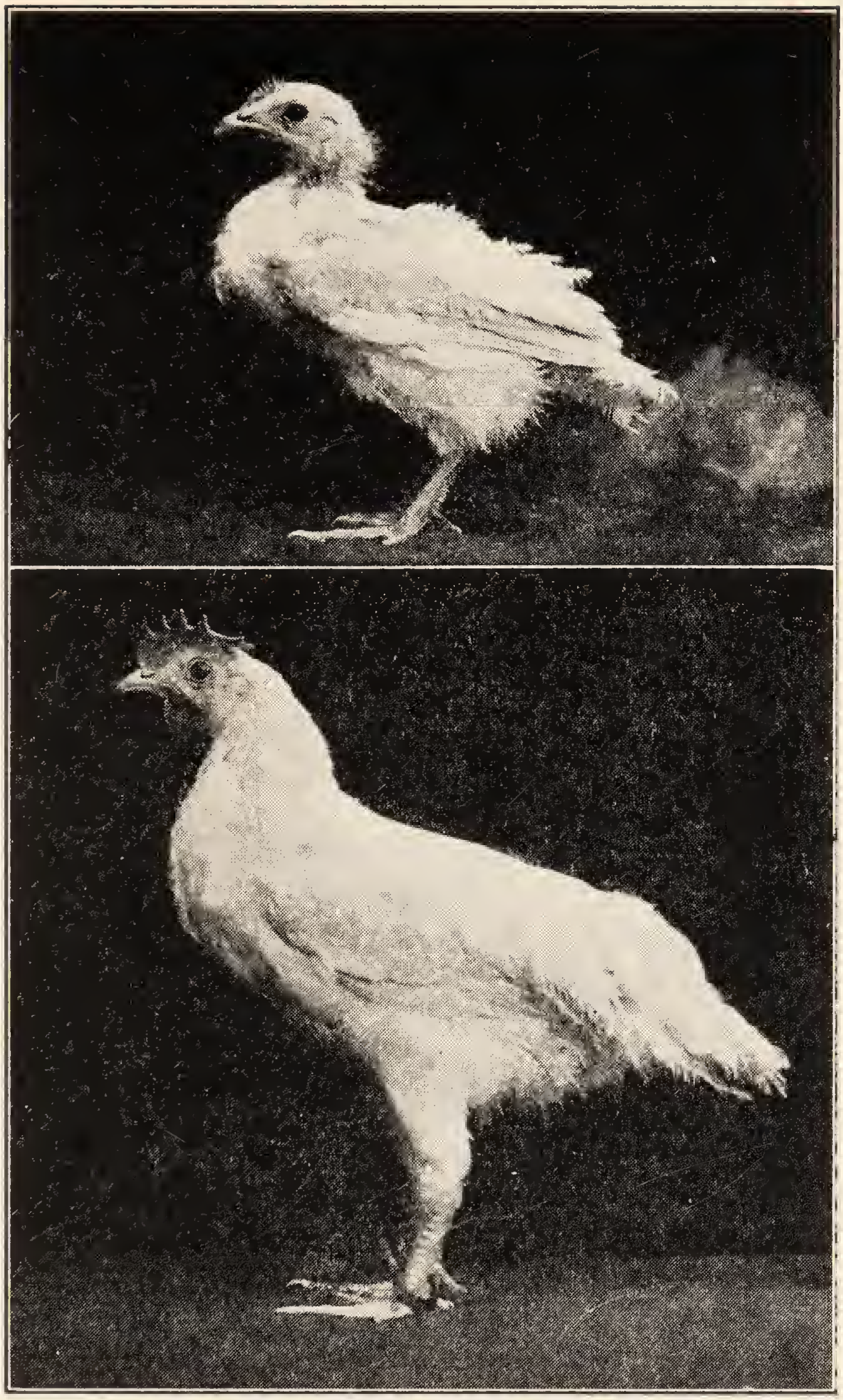
CHAPTER XIV

VITAMIN G AS A REGULATOR OF BODY PROCESSES

Discovery

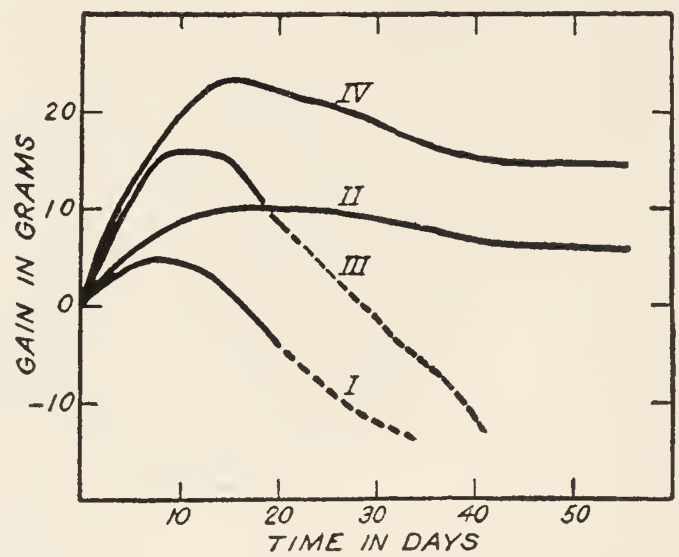
Many irregularities in the behavior of foods containing "water-soluble vitamin B" engendered skepticism as to whether all the properties attributed to vitamin B really belonged to a single vitamin. It was found that green vegetables, roots, and tubers, while capable of promoting good growth in rats, were not so efficient in curing polyneuritic pigeons. By 1919 the assumption that vitamin B was a single substance both antineuritic and growth promoting was being definitely challenged and a little later it was shown that when yeast was heated for two hours under pressure (autoclaved) its power to cure polyneuritic pigeons was destroyed, yet it could still stimulate growth in a rat. For several years reports of this kind became increasingly common. For example it was found that rats would not grow normally if a large amount of rolled oats were the only source of vitamin B, although polyneuritis was quickly cured. Yet the addition of only a little (5 per cent) of brewers' yeast, heated till it would no longer cure polyneuritis in a pigeon, brought about normal rat growth. It was quite apparent that the autoclaved brewers' yeast added something necessary for the rat which the oats lacked. Another interesting experience of this same period (1926) was with regard to corn as the only source of vitamin B for chicks. With as much as 30 per cent of whole corn in the ration, polyneuritis was prevented but growth was very poor; but if one third of the corn were replaced by dried brewers' yeast, excellent growth resulted. The difference in the chicks on the two rations is shown in Fig. 89.



(*Courtesy of Drs. S. M. Hauge and C. W. Carrick*)

FIG. 89.—The upper chicken was fed from hatching for 10 weeks on a diet containing 30 per cent of corn. It showed no symptoms of polyneuritis but failed to grow well, and attained a weight of only 200 grams. The lower chicken was fed the same diet as the one above, except that one third of the corn was replaced by an equal weight of dried brewer's yeast. The combination resulted in normal growth and a final weight in 10 weeks of 485 grams, showing that two vitamins were involved.

Work of the United States Public Health Service under the direction of the chief surgeon, Dr. Joseph Goldberger, and his associates, growing out of studies of pellagra which will be referred to in Chapter XV, led to the announcement in 1924 of "a heretofore unrecognized or unappreciated dietary factor," present in brewers' yeast, in milk, and in lean beef, but very low or lacking in soy beans, cowpeas, butter, and cod liver oil. Feeding experiments on rats with



(Courtesy of Drs. H. C. Sherman and J. H. Axtmayer)

FIG. 90.—Growth Record of Rats Showing Supplementary Effects between Whole Wheat and Autoclaved Yeast.

I. Failure to grow on a diet free from vitamins B and G.
II. Practically stationary weight when 0.8 gram daily of ground whole wheat was added (much vitamin B).
III. Failure to grow when 0.8 gram of autoclaved yeast was added (no vitamin B).
IV. Growth when 0.4 gram whole wheat and 0.4 gram autoclaved yeast were added. (The wheat furnished vitamin B; the yeast, vitamin G.)

a vitamin B free diet generously supplemented by an antineuritic extract of corn resulted in rapid decline and death of the rats, but a combination of relatively small amounts of the corn extract and autoclaved yeast induced excellent growth.

It took some time for investigators to perceive the full significance of such findings, but an experiment by Sherman and Axtmayer in 1927 helped to clear the confusion resulting from varying results with heated (autoclaved) and unheated yeast, and from using different kinds of food as the source of vitamin B. They fed one group of rats a vitamin B free diet to which 0.8 gram daily of ground whole wheat

was added, and no growth resulted. They fed another group the same amount of autoclaved yeast with no more success. To a third group of animals they gave 0.8 gram of a mixture of the two in equal parts. The result was much better growth, as shown in Fig. 90. It was evident that each food material furnished something the other lacked for growth, or in other words that there were two different growth promoting substances one of which was antineuritic (the whole wheat) while the other (the autoclaved yeast) was not. A further test of skim milk as the source of both vitamins showed that milk is very effectively supplemented by whole wheat, which means that it is not as rich in the antineuritic vitamin as in another growth promoting one found in autoclaved yeast.

From these and numerous other researches it was established beyond doubt by 1928 that there was an antineuritic vitamin B (B_1) and another growth promoting vitamin which was incapable of curing polyneuritis, designated vitamin G (also known as B_2).

Since the antineuritic vitamin in any extract could be destroyed by heating, such materials as yeast and milk, now known to be rich in vitamin G were used as the source of concentrates for the chemical study of vitamin G as well as investigation of its nutritional properties. In the Department of Chemistry of Columbia University Dr. Lela E. Booher by 1933 had achieved a high concentration of the vitamin from whey powder, so that the final product had 2,000 times the vitamin G activity of the original milk. It was adequate for growth when fed in conjunction with a concentrate of vitamin B (B_1).

Meanwhile another line of investigation had opened new vistas for students of biological problems. It had been known for a century that there were in plant and animal tissues water-soluble, yellowish pigments having a greenish fluorescence, but no one had given any particular attention to their possible function. In 1914, in a paper from the Dairy Chemistry Laboratory of the University of Missouri,

Dr. Leroy S. Palmer and L. H. Cooledge wrote: "The natural yellow color of cows' milk is caused by two entirely different kinds of pigments; the principal one of the two pigments is found in milk fat. It has recently been found by one of us to be a mixture of carotin and xanthophylls, principally carotin, which are transmitted to the milk fat from the green feeds of the cow. The secondary or minor pigment has not been identified. Its presence in the milk is largely masked by the white color of the caseinogen and is only seen in the whey which remains after the caseinogen has been coagulated. The pigment is then seen imparting the usual greenish color to whey." [1] The "carotin" we recognize, of course, as the carotene of today, the precursor of vitamin A. Little did these authors dream that both pigments were vitamins! It was not until nearly twenty years later that the "lactochrome's" biological significance began to be understood; not until in 1932, Professor O. Warburg and W. Christian at the Kaiser Wilhelm Institut für Zellphysiologie, Berlin, reported some of their investigations of the "yellow oxidation enzyme" which plays an important part in cell respiration, and which is formed by the combination of this pigment with phosphoric acid and a special protein. The next year the yellow pigment was isolated from whey and egg white in pure crystalline form, 0.06 gram of crystals being obtained from about 750 gallons of milk, by Dr. R. Kuhn and others at the University of Heidelberg in Germany. Analysis showed that it belongs to a group of compounds known as flavins. These crystallize in yellow-brown needles which when dissolved in water give a yellow solution with a greenish-yellow fluorescence. According to the substance from which they were extracted they were called lactoflavin, ovoflavin, etc., but very soon the chemical structure was worked out by chemists already conversant with the complex chemistry of plant pigments, especially Euler in Sweden and Karrer in Switzerland, and they were

[1] Palmer, L. S., and Cooledge, L. H. "Lactochrome—The Yellow Pigment of Milk Whey." *Journal of Biological Chemistry,* Vol. 17, page 251 (1914).

found to be all of one sort, riboflavin. Synthesis of this compound was accomplished by Euler in 1934.

Along with the chemical studies went biological tests and the fact that growth was stimulated by very small quantities suggested that it was a water-soluble vitamin belonging to

Fig. 91.—Crystals of Pure Vitamin G (Riboflavin).

the vitamin B group, but it would not with vitamin B_1 support growth in a rat unless something else present in yeast was added at the same time.

This caused a little confusion at first, because Booher was able to get growth by adding her concentrate only, and yet the concentrate had the characteristics of flavin, the deep orange-red color and the yellowish-green fluorescence in a water solution. However, as she purified her material further, she, too, found that something was lost which was a factor

in growth and that her concentrate plus pure crystalline vitamin B_1 also needed a supplement and decided that "vitamin G is itself the water-soluble yellow pigment or the pigment is an integral part of the vitamin." [1] Subsequent work has made it clear that what was at first thought to be a single vitamin was a mixture, of which this water-soluble yellow pigment, riboflavin, was only one part. In the next chapter, the other factors will be discussed as far as present

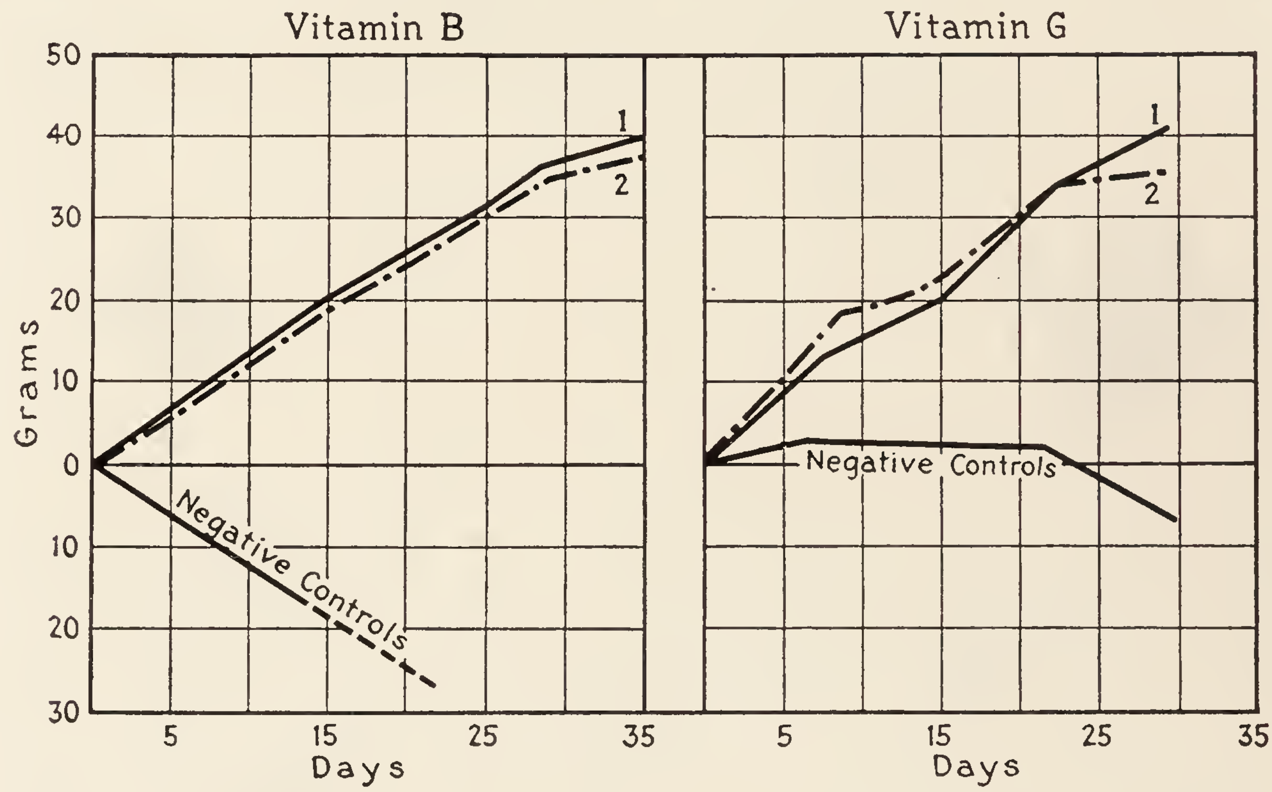


Fig. 92.—Growth curves of rats in vitamin B and vitamin G studies. The negative controls in the vitamin B study (average of 28 animals) received none of the vitamin and declined in weight very rapidly, dying within a month. The negative controls in the vitamin G study (average of 15 animals) maintained a fairly constant weight for three weeks, then declined slowly in weight for about ten days before they died or were killed. The sources of vitamins B and G for the animals that grew at a good rate were peas preserved by quick freezing (1) and fresh raw peas (2).[2]

knowledge goes. Vitamin G, whenever referred to in this book, is riboflavin.[3]

The Promotion of Growth

When young rats are placed at weaning time upon a diet deficient in vitamin G they do not decline in weight im-

[1] Booher, L. E. "Further Studies on the Concentration and Chemical Nature of Vitamin G." *Journal of Biological Chemistry*, Vol. 107, page 591 (1934).

[2] Rose, M. S., and Phipard, E. H. F. "Vitamin B and G Values of Peas and Lima Beans under Various Conditions." *Journal of Nutrition*, Vol. 14, page 55 (1937).

[3] The numerical formula is $C_{17}H_{20}N_4O_6$. For the structural formula see Sherman's *Chemistry of Food and Nutrition*, 5th edition, page 408. The Macmillan Co. (1937).

mediately but usually grow a very little or remain stationary for ten days or two weeks, after which they neither gain nor lose for about three weeks, then decline slowly for a week or two more and die after having survived complete deprivation for about two months. Animals deprived of vitamin B decline very rapidly after an initial period of about ten days during which they gain some weight. Their death

FIG. 93.—The upper rat was placed at weaning on a diet lacking vitamin G. This picture was taken after 16 weeks, when the animal weighed only 60 grams. The control animal, started at the same age on an adequate diet, weighed 245 grams at the end of the 16-week period.

is due largely to starvation because of their loss of appetite. Figure 92 shows this contrast between the behavior of a group of rats lacking vitamin B and that of a group lacking vitamin G. The curves for the "negative controls" begin at the point where the animals have ceased to gain weight.

Such a weight record for animals deprived of vitamin G is obtained only when they are "harnessed" or put into a sort of straight jacket so that they cannot follow their natural habit of consuming their feces, and each one put in a separate cage to prevent any possibility of getting feces from a

partner. The feces contain a small amount of vitamin G synthesized by intestinal bacteria. An animal kept on a vitamin G-deficient diet but not harnessed is shown in Fig. 93. This animal was able to survive for 17 weeks without any appreciable change in weight until the last week. Its mate, the lower animal in Fig. 93, was fed an adequate diet and at the end of 16 weeks weighed 245 grams. The growth curves

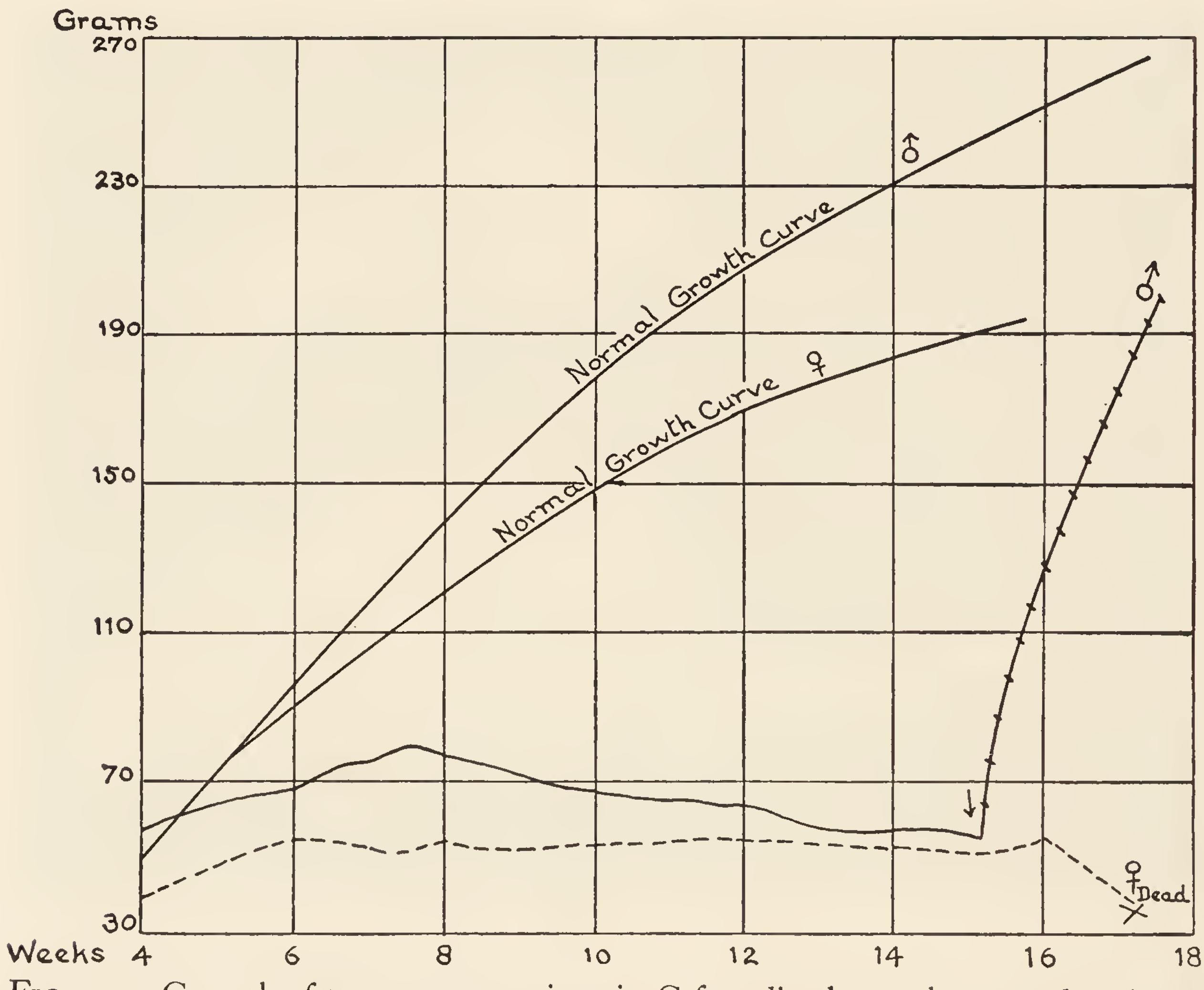


FIG. 94.—Growth of two rats on a vitamin G free diet but unharnessed and caged together. Note the long period of slowly declining weight in the male (♂) and of almost stationary weight in the female (♀). At the end of 15 weeks the male was placed on an adequate diet and rapidly gained in weight. The female, continued on the vitamin G free diet, soon declined rapidly and died in the 17th week.

of two rats fed a vitamin G-deficient diet but unharnessed and caged together are shown in Fig. 94. The female died after 17 weeks; the male was changed to an adequate diet after 15 weeks and nearly quadrupled its weight in the next two weeks.

Pure crystalline vitamin G, whether derived from a food like milk or eggs or made in the laboratory, brings a quick response when fed to an animal which has been deprived of

the vitamin. As little as two millionths of a gram has been found to bring a growth response in a rat.

The Health of the Skin

After young rats have been on a vitamin G-deficient diet for seven or eight weeks, other signs of nutritional failure besides inability to grow begin to manifest themselves. If there is a trace of vitamin G in the diet they live longer and there is more opportunity for pathological symptoms to develop. In a recent study, Mrs. E. P. Daniel and Dr. H. E. Munsell of the Bureau of Home Economics of the United States Department of Agriculture found that animals kept on a good diet until six weeks of age and then put on one almost but not absolutely deficient in vitamin G never grew, but maintained their initial weight for over a year. They also found that whatever the age, from 4 weeks to 18 months, and regardless of whether they declined rapidly in weight or maintained themselves at stationary weight for a long time, the other symptoms of deficiency were practically the same. Loss in weight was followed by a loss of hair, technically called alopecia, which was most marked in the younger animals. It occurred in irregularly distributed patches, beginning generally at the side or on top of the head, the sides or front of the neck, or about the shoulders. In severe cases it led to almost complete denudation of head, trunk, and neck. The early stages of this denudation may be seen in the animal in Fig. 93, whose coat has a distinctly "moth-eaten" appearance. Sometimes the hair will fall out about the eyes, giving the animals a peculiar "spectacled" appearance. These authors also report finding enormous hairballs in the stomach, which is not strange, considering how easily the fur pulls out.

Other symptoms are a sore mouth, inflammation starting at the corners and sometimes progressing over the whole lower lip; also a bloody, swollen nose, matting of the fur on the hind paws, with subsequent thickening of the skin, cracking and desquamation, leaving a denuded pale pink, glistening skin.

These symptoms accord well with those described by Goldberger in 1926, and offered by him as evidence for the existence of another vitamin associated with vitamin B but possessing very different properties. They have also been verified by other investigators, and have led to the application of the term "antidermatitic" to vitamin G. Confusion arose, however, owing to the fact that on different types of diets, or using different vitamin G concentrates, the symptoms of dermatitis were not always the same nor were they always cured by pure crystalline vitamin G. Further research has led to the recognition of two types of dermatitis and to the differentiation of another vitamin, variously called "factor Y," "vitamin B_6," or "vitamin H," which will be considered in Chapter XV. This discovery does not invalidate the conclusion that vitamin G is a definite factor in the health of the skin and the preservation of the fur coat of the rat.

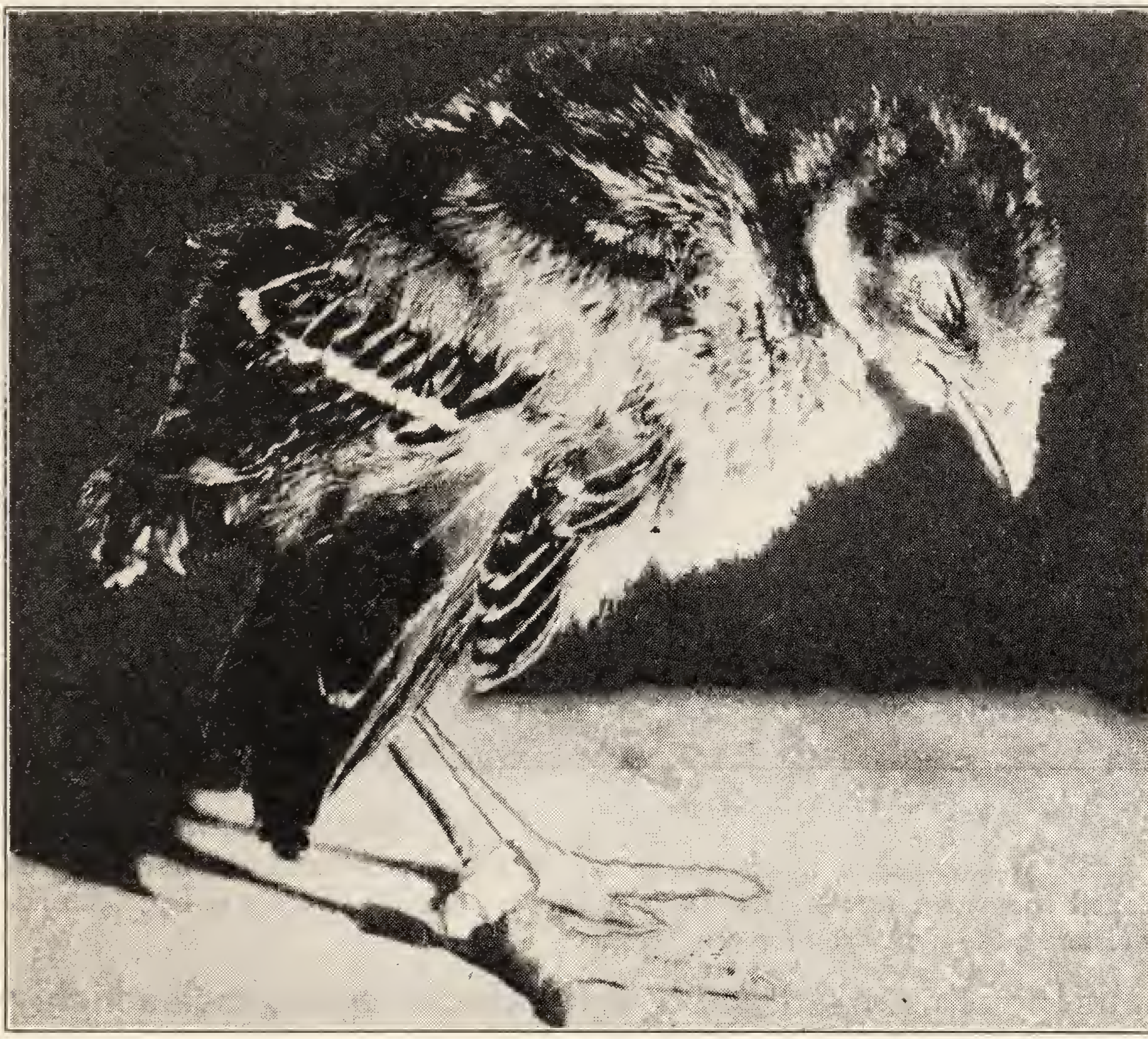
The Health of the Eyes and the Prevention of Cataract

In their classic paper in 1926,[1] Goldberger and Lillie of the United States Public Health Service remarked: "After a variable period following the arrest of growth already mentioned, there has been observed in many of the animals so fed a tendency for the lids of one or both eyes to adhere together with, in some instances, an accumulation of dried secretion on the margin of the lids." The same phenomenon was observed by various later workers. Sherman and Sandels noticed it in rats on diets in which no other part of the vitamin B complex was lacking except vitamin G, along with loss of hair around the eyes, giving a "spectacle-like" condition. That it occurs in turkeys as well as rats has been interestingly shown by Drs. S. Lepkovsky and T. H. Jukes as indicated in Fig. 95.

More intensive study of the eye was not made until 1931, when Dr. Paul L. Day of the University of Arkansas, re-

[1] Goldberger, J., and Lillie, R. D. "A Note on an Experimental Pellaga-like Condition in the Albino Rat." *U. S. Public Health Reports*, Vol. 41, page 1025 (1926).

ported that on a diet entirely free from vitamin G all but two of a group of 37 rats developed a whitish appearance of the eyeball which upon examination with the ophthalmoscope



(*Courtesy of Drs. S. Lepkovsky and T. H. Jukes*)

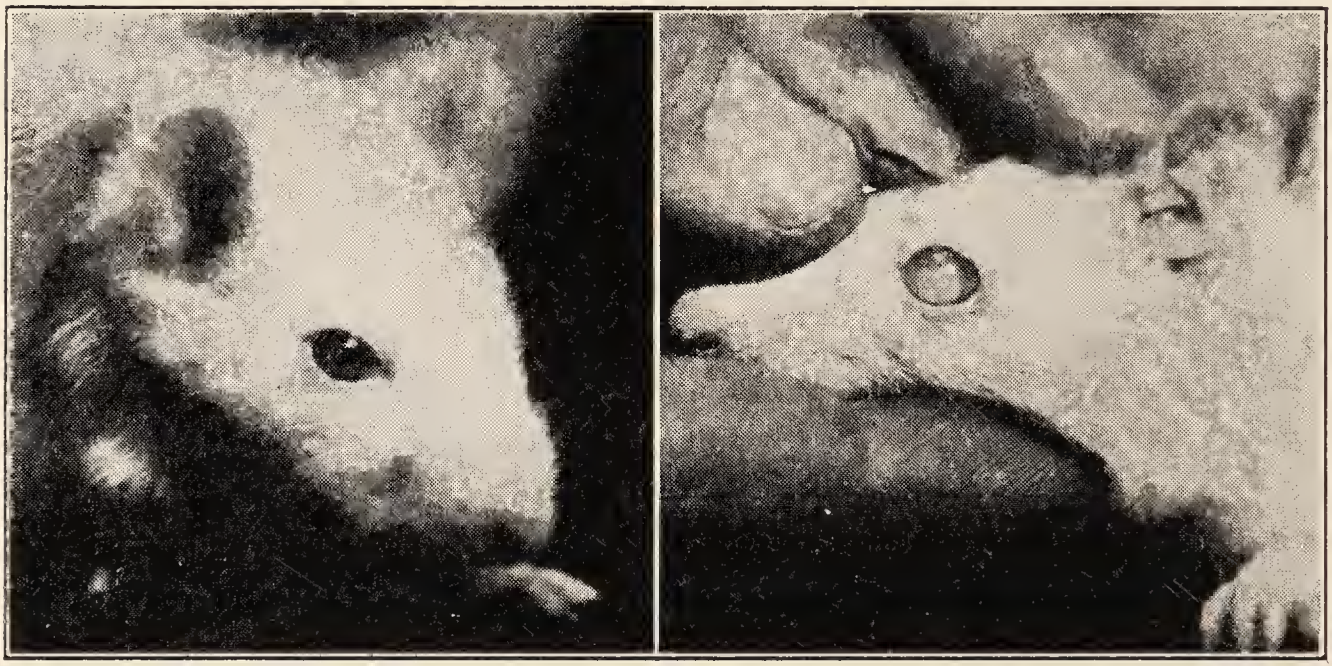
FIG. 95.—A Turkey after 17 Days on a Vitamin G Deficient Diet, Showing the Eyelids Stuck Together and Incrustation of the Mouth and Nostrils.

proved to be due to cataract. The studies with rats were later continued with mice, chicks, and monkeys, and in these species, too, cataract developed upon withholding vitamin G from the diet and was prevented by the administration of pure, synthetically prepared riboflavin.[1]

Usually the cataracts appeared in both eyes of the rats between the 60th and 87th day, but Fig. 96 shows one animal in which a cataract developed first in one eye (left view) and was prevented from appearing in the other eye by immedi-

[1] Day, P. L. "Vitamin G Deficiency." *American Journal of Public Health*, Vol. 24, page 603 (1934).

ately giving vitamin G. The eyelids were swollen and almost hairless, but when the vitamin was given new hair began to grow, not only on the eyelids but over the whole body, and a general rejuvenation took place except that the lens opacities did not clear up, as there is no mechanism for the repair of such a damage. Just what bearing this may have on cataract in man is still unknown, but as Day says, "A deficiency that re-



A B

(*Courtesy of Professor Paul L. Dcy*)

FIG. 96.—Two views of the same rat, B taken after cataract developed in the left eye as a result of vitamin G deficiency; A after vitamin G had been administered, the right eye thus being saved.

sults in such marked and irreparable damage to such a highly specialized tissue as the lens should not be considered lightly."

Maintenance of Health and Vigor of All Ages

The most extensive investigation of the effects of vitamin G on general health and vigor are those of Sherman and Ellis, who have found that when parallel groups of rats were fed at graded levels of vitamin G intake, beginning with one which supported normal growth and apparently good health, successively more liberal levels resulted in more rapid growth, earlier maturity, better vigor as shown by ability to bear young, postponement of the signs of senility and "enhancement of nutritional well-being," or as McCollum has aptly said, "preservation of the characteristics of youth." Animals fed more vitamin G than is required for normal growth

to adult size not only lived longer, but had a longer period of adult vigor and a relatively short period of senility. In Fig. 97 is shown a rat that had just enough vitamin G to ward off death. It became weak and depressed, but living a sheltered life, protected from strain and other vicissitudes was able to continue a miserable existence for many months.

Withholding of vitamin G causes no abrupt and complete loss of appetite, as does deprivation of vitamin B, but the

(Courtesy of Professors H. C. Sherman and M. R. Sandels)

Fig. 97.—This rat is 8 months of age and weighs less than at the age of 4 weeks. A normal animal of this age will weight from 200 to 300 grams. The failure to grow and senile appearance are due to lack of vitamin G.

impulse to eat is depressed somewhat, so that about two thirds as much food per gram of rat is consumed as would be eaten by a normal animal. This means, of course, a lowering of the supplies to the body of all essentials and unless the diet is extraordinarily well fortified, there are likely to be secondary effects due to deficiencies of other essentials. This appears particularly to be the case with vitamin B, so that vitamin G shortage is often complicated by a further failure of appetite and symptoms of polyneuritis.

Digestion is usually impaired, with general weakness and loss of good muscle tone. Sherman has admirably summarized the general situation thus: "Vitamin G is essential to growth and to normal nutrition at all ages. When the food

is poor in vitamin G for any considerable length of time, digestive disturbances, nervous depression (different from the symmetrical polyneuritis of vitamin B-deficiency), general weakness and deterioration of tone, and an unhealthy condition of the skin are apt to develop; the incidence of infectious disease is likely to be increased, vitality diminished, life shortened, and the period when life is at its prime greatly curtailed by the early development of the physical condition of old age." [1]

Measurement

Though other animals are sensitive to a vitamin G-deficiency the rat has been most widely used for quantitative tests of this vitamin. Sources of still unidentified essentials of nutrition are sufficiently well known that a diet lacking vitamin G can be prepared from highly purified casein (which tenaciously holds traces of the vitamin), a salt mixture which long experience has shown to be adequate, cod liver oil for vitamins A and D, and an extract of whole wheat, yeast, or rice polishings which will contain vitamin B and the other necessary vitamins of the vitamin B complex but will be free of vitamin G if the extraction is made under properly controlled conditions.

To make a quantitative test, young rats, weaned at the age of 28 days from mothers on a standard adequate diet are confined singly in cages with raised screen floors and "harnessed" so that they cannot put their paws into their mouths. After two or three weeks on the vitamin G-deficient diet, to exhaust reserves of vitamin G, the test proper begins, various amounts of the material to be tested being added to the basal diet until that amount is found which gives a gain averaging two to three grams per week during a period of four or five weeks. This amount is called a Sherman-Bourquin unit.

Sources

In most of the foods which contain it, vitamin G is associated with vitamin B and with other water-soluble vita-

[1] Sherman, H. C. *Food and Health*, page 151. The Macmillan Co. (1934).

mins which have been discovered to exist in the so called vitamin B complex. The only food in which vitamin G is known to occur without vitamin B is white of egg. The richest known source is dried brewers' yeast, but liver is almost as rich, weight for weight, and kidney only a little less so. Muscle meat, whether beef, lamb, or veal, is about one tenth as rich as liver. The egg yolk is over twice as rich as the egg white. Milk is according to Sherman "doubtless the most important source of vitamin G for the American and European peoples." A quart of milk will furnish as much as four or five eggs, or a pound and a quarter of lean beef, or about two ounces of liver. A pound of American cheese yields about three times as much as a quart of milk. Weight for weight American cheese is about equal to egg yolk.

Among vegetable foods, green leaves are the best sources, and turnip tops and beet tops exceed in value other members of this group which have been tested, being weight for weight about twice as rich as eggs. Roots and tubers and fruits so far as investigated have the vitamin in very low concentration.

The cereal grains are in general poor sources. In fact, the poverty of whole wheat and whole corn in this vitamin was one of the factors which led to its identification as a separate vitamin. The cereals rank with the potato and the apple as among the poorest of vegetable foods which have been investigated. Most of the vitamin is in the germ, and when separated from the rest of the grain it becomes an excellent source, being fully twice as rich, weight for weight, as egg yolk. The dried legumes have been little investigated. Dried Lima beans are a good source and dried soy beans are three times as rich as Lima beans. Dried whole green peas are slightly richer than dried Lima beans, and both fresh peas and Lima beans compare favorably with spinach, watercress, and other green leaves.

Heating does not readily destroy this vitamin, consequently canned foods are about as rich in it as the original

FIG. 98.—Foods Yielding about 50 Units of Vitamin G.

	Grams		Grams
Lettuce	79	Orange	220
Spinach	50	Peas, dried	14
Water cress	50	Beef, lean	50
Beet tops	20	Cabbage	100
Carrot	129	Liver, beef	6
Banana	258	Cauliflower	83
Potatoes	250	Egg white	50
Milk	156	Egg yolk	22

food before preservation. Vitamin G values for foods for which such data are available are given in Table I of the Appendix.

Requirement

Vitamin G has been too recently isolated from the other vitamins with which it is so closely associated in nature for studies of requirement to have extended beyond experimental animals. That the margin between a minimum which will support normal growth to maturity and an optimum which will increase health and vigor throughout the whole life span is wide is shown by the work of Sherman and Ellis. They conclude from their experience with diets at four levels of vitamin G intake, the lowest of which was adequate for normal growth and reproduction that "for the best results the food should furnish at least three or four times as much vitamin G as is needed to prevent the appearance of any specific sign of deficiency."

To interpret this in terms of human experience at the present time we are forced to rely upon studies of food intake under various conditions. From studies of families on a very low economic level, whose diets are manifestly below the line of safety with regard to the group of vitamins which constitute the vitamin B complex, it is possible to get some suggestions as to where the lower limit of safety lies. In an investigation made by Dr. H. K. Stiebeling and Dr. H. E. Munsell of the Bureau of Home Economics, United States Department of Agriculture, of 73 South Carolina farm families close to this nutritional borderline, it was found that 14 families whose food supply was sufficient to prevent the development of such a specific nutritional disease as pellagra used on the average $2\frac{1}{4}$ cups of milk, about 3 ounces of lean meat, and about 3 ounces of succulent vegetables and fruit per person per day. In strong contrast to these families were many in which less than $\frac{1}{5}$ cup of milk, and also less of the other foods mentioned above were regularly consumed, and in which there were many cases of pellagra. Twenty-

eight of these latter families were given dried skim milk or evaporated milk equivalent to approximately a pint or a quart of fluid milk, with the result that where previously out of 134 people there had been 76 cases of pellagra, the number was reduced to 13. The highest incidence of pellagra was among the adult women, the mothers of families, and indicated either that they need more of the protective foods or that they habitually eat less, especially when food is scarce.

That they may eat less is indicated from a study in Philadelphia of fluid milk consumption in 3,413 families made in 1934 by Pennsylvania State College and the United States Department of Agriculture. This was encouraging in showing that regular milk drinking had increased in a ten-year period, especially among children under 13 years of age, but it also revealed that a smaller number of mothers drank milk than any other member of the family, only 17 per cent of the total number of mothers taking it regularly.

That mothers can profit from very liberal intakes of the vitamin B complex has been shown in the studies of Donelson and Macy in Detroit. Mothers furnishing milk for their own babies and an average of 13 ounces more for the Mothers Milk Bureau, eating diets which were adequate according to present standards, were given in addition 10 grams of yeast furnishing 75 to 150 units of vitamin G, with the result that the vitamin G in their breast milk was increased 50 per cent and at the same time the mothers "experienced less fatigue and had a more satisfactory feeling of well-being."

According to Sherman, milk in its various forms is the most important source of vitamin G in American diets. It would seem that with an allowance of a pint of milk for every adult and a quart for every child, supplemented by generous amounts of fruits and vegetables, and some meat and eggs, the intake of vitamin G will be liberal. On this basis a tentative dietary standard of 600 Sherman-Bourquin units of vitamin G per day for the adult man, at least 400 units per day for children up to the age of 10 years, and at least

20 units per 100 calories thereafter has been used in this book. It is believed that this will provide "four times the amount required for adequacy" as suggested by Sherman and Ellis. But in pregnancy and lactation it is desirable that still more liberal amounts be used.

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CHAPTER XV

VITAMINS OF UNDETERMINED SIGNIFICANCE IN HUMAN NUTRITION

Just as investigations of the functions of the glands of internal secretion have revealed a multiplicity of hormones undreamed of even ten years ago, so the researches on the sources and functions of the vitamins are bringing to light a larger number of these "food hormones" which are also controlling factors in the infinitely complex organization of the living body. In this chapter two of these will be discussed briefly, although their significance in the human organism is still unknown. One of them has been isolated, crystallized, and analyzed—vitamin E; the other has been too recently differentiated from the others in the vitamin B complex to have been fully identified, although concentrated preparations have been prepared—vitamin H, also commonly designated B_6. Still a problem in the vitamin field is the nature of the so called pellagra-preventing substance or substances which occur in foods serving as good sources of the vitamin B complex. That pellagra is preventable by dietary measures has been demonstrated; the nature of the active agent in this control is still under investigation and only a brief résumé of what has been accomplished is in order at this time.

Vitamin E

Discovery. The first positive indication that a diet which would enable an animal to grow to maturity in apparently excellent health might still be inadequate for reproduction was furnished in 1920 by Professor H. A. Mattill of the State University of Iowa, who was seeking an answer to the question: Is milk, which so admirably meets the needs for

growth of the young, a food which will furnish all dietary requirements through the whole life span? Young rats were found to prosper till they approached maturity (at the age of about two months), when they grew somewhat more slowly and failed to reproduce. Various additions to the diet, such as iron, yeast, and butter, were tried without success and the investigators were at a loss for an explanation. This was furnished in 1922 by Professor H. M. Evans of the University of California. As an anatomist interested in the physiology of reproduction he had begun in 1921 to study the influence of diet upon the estrus cycle of the rat and very soon discovered that failure of ovulation occurred regularly on diets insufficient in vitamin A, even though they furnished enough for fair growth. Further investigation with a highly purified ration, thought to be adequate in everything but vitamin A, revealed that it could not be made satisfactory for reproduction even when much vitamin A in the form of cod liver oil was added.

The animals raised on this diet had every appearance of health, being "of splendid size, sleek-coated and active" but they bore no young. They would exhibit normal estrus cycles, breed, ovulate, and conceive, but something would happen to the placenta which resulted in the death of the fetus. When the character of the protein of the diet was changed or increases made in the amounts of vitamins A, B, and D there was no improvement. But fresh lettuce was very effective. The possible influence of vitamin C was ruled out because whole wheat or a powder of dried lettuce leaves heated to destroy vitamin C was curative, too. Careful work with wheat embryo revealed a remarkable potency, only one fourth of a gram daily being needed to restore normal fertility. Evans concluded that there was a special fertility factor and it soon came to be known as vitamin E.

The oil of the wheat germ was now treated to remove the fat and so concentrate the vitamin which was found in the residue. The oil of lettuce was also extracted and the nonfatty residue was found to be very potent. Finally, in 1935,

Evans and his associates, O. H. and G. A. Emerson, obtained from wheat germ oil a crystalline compound belonging to the alcohols of high molecular weight (sterols), which was potent for the prevention of sterility. To this they gave the name alpha-tocopherol.[1]

The Prevention and Cure of Sterility

On diets low in vitamin A ovulation ceases in the female and her reproductive system becomes so injured that fertilization and implantation usually fail. In the male there is epithelial degeneration resulting in permanent impairment of sex function. Insufficiency of vitamin B, if only partial, results in the female in cessation of the estrus cycle and in the male in complete loss of sex interest. If vitamin B is entirely lacking there is degeneration of the tissues of the sex glands, both ovaries and testes. Vitamin C has been found in the *corpus luteum*, and assures an adequate supply for the developing fetus, at least in the early stages. Vitamin G has such widespread significance in cell oxidation processes that no development appears to be possible without it. The function of vitamin E is more highly specialized and its lack does not prevent the development of a normal individual although, in the rat at least, it does result in sterility. In the male there is destruction of the germ cells; in the female the estrus cycle is normal and there is no failure of ovulation, the developing ova are fertilized and implanted and the embryos begin to grow rapidly, but often by the eighth day, when more than a third of the gestation period has been completed, retardation in development can be observed, and at some time between the twelfth and twentieth day fetal death occurs, followed by resorption of the fetus. In no other type of dietary deficiency does this peculiar failure of placental function occur.

Vitamin E is transferred from mother to offspring during intrauterine life. This is proven by the fact that the tissues

[1] Evans, H. M., Emerson, O. H., and Emerson, G. A. "The Isolation from Wheat Germ Oil of an Alcohol, α-Tocopherol, Having the Properties of Vitamin E." *Journal of Biological Chemistry*, Vol. 113, page 319 (1936).

of newborn rats cure female dietary sterility. If rats of proven fertility are placed on a diet lacking vitamin E, they will remain fertile for three or four months, thus showing that vitamin E can be stored in the body. Further evidence on this point has been obtained by feeding to a certain number of sterile females various tissues (liver, muscles, fat) derived from other sterile females, and to another group of sterile animals tissues from animals of proven fertility. In all instances the tissues of rats whose diet contained vitamin E provoked fertility, but in no case did the tissues of sterile rats cure sterility in another animal.

There is as yet no clinical proof as to whether or not vitamin E is required by human beings. At all events the amounts needed are certainly small and its very wide distribution in food materials insures a considerable intake. It occurs in the greatest richness in the oil of the wheat germ, but is found in abundance in seeds and green leaves generally. In animal tissues it is present in low concentration, more being found in muscles and body fat than in the visceral organs. It occurs also in milk fat, but, as in case of the other vitamins, the amount present in milk is influenced by the character of the diet of the lactating animal.

Pellagra

In 1914 pellagra, a disease which had been more or less prevalent in certain sections of Europe for 200 years, began to develop alarmingly fast in some of our southern states. Goldberger determined to investigate its cause, and this decision was timely, for in 1915 over ten thousand persons died of the disease in the United States, and by 1917–18 two hundred thousand were suffering from it.

Pellagra is a peculiar disease, seasonal in its outbreaks, 90 per cent of the cases having their onset in the period from April to July, with remissions in the late fall and winter. Its symptoms are many and varied, but among the most typical is a skin eruption which at first resembles sunburn, but later becomes dark and makes the skin rough and scaly. It

attacks only certain parts of the body surface, particularly the backs of the hands in adults and of the feet in children. Other parts not infrequently attacked are the sides or front of the neck, the face, elbows, and knees. Another marked peculiarity is its tendency to appear at about the same time on both sides of the body. If the back of one hand or one cheek is affected, the corresponding part on the opposite side is involved also. Accompanying the skin eruption are soreness of the mouth and redness of the tongue, indigestion and diarrhea, and disturbance of the nervous system leading in the severest cases to insanity. The mortality records tell the smallest part of the misery it entails, due to lowered physical and mental standards and reduced capacity for the enjoyment of life. The poor man is always the chief victim, but the limitation of the disease to certain rather clearly defined geographical areas indicates that other factors besides poverty are involved. In Great Britain the endemic disease of the poor is rickets; in the Far East it is beriberi; in the cotton mill villages of the south and in southern rural districts where cotton is practically the only crop, it is pellagra.

The first scientific description of the disease was written by a Spaniard named Casal in 1735. He noted the very poor diets of the pellagrous districts of Andalusia and attributed the disease to faulty nutrition. A few years later it was recognized and named in Italy. Subsequently it spread into France, Hungary, Rumania, Turkey, and Greece. In 1845 a French physician, Dr. T. Roussel, wrote a treatise on pellagra in which he, too, pointed out that it is a nutritional disease and recommended broth, meat, milk, eggs, and fish as the best cure. At the close of the World War pellagra broke out in Egypt in camps for Armenian refugees and for prisoners of war. Doctor W. H. Wilson of Cairo, who studied the diets, thought them too low in protein and cured the victims by the addition of meat and milk to their high cereal diets.

In the parts of the south where pellagra was becoming a

scourge in 1914, the main agricultural crop was cotton and the people subsisted on foods bought in the local groceries, mainly cornmeal and grits, white flour, polished rice, sugar, molasses, and fat pork. In mill villages there were no butcher shops nor dairies and even in the rural districts few persons kept any cows, poultry, or other live stock. A survey made by Goldberger convinced him that "the suspicion of pellagra may with confidence be dismissed in one who is a habitual milk drinker and meat eater," but he determined to put the matter to the test, just as Eijkman had done in case of beriberi in Java, and see whether pellagra could be induced in healthy men by dietary measures. He selected for his experiment the farm of the Mississippi State Penitentiary where there was a camp well isolated from the surrounding communities (to rule out the possibility of bacterial infection) caring for some 70 to 80 convicts. On promise of a pardon from the governor of the state, twelve men volunteered to serve as subjects (later one was dismissed) and at the beginning of February, 1915, they were quartered in a small screened cottage and kept under guard day and night. Until April 19 they had the usual prison fare and there were no signs of pellagra. They were then put on an experimental ration consisting chiefly of cornmeal and grits, cornstarch, white flour, rice, cane syrup and sugar, sweet potatoes, and pork fat, with exceedingly small amounts of turnip greens, cabbage, and collards. The average protein intake was only 6 per cent of the total calories and from 80 to 97 per cent of the total protein came from the cereal foods. Six men developed symptoms which were deemed sufficient to justify a diagnosis of pellagra by November 1, when the experiment terminated. No one in the camp not on the volunteer squad showed any sign of the disease. In concluding the investigation Goldberger said: "In relation to the study of pellagra this study suggests that the dietary factors to be considered as possibly essential are (1) an amino acid deficiency, (2) a deficient or faulty constitution of the mineral supply, possibly, but doubtfully, (3) a deficiency of the fat soluble

vitamine intake, and perhaps (4) an as yet unknown (vitamine?) factor. As to which or what combination (or combinations) of these constitutes the specific pellagra-producing dietary defect or defects remains to be determined." [1]

Studies on human subjects in certain asylums in which pellagra recurred regularly showed that addition to the diet of purified protein only was without effect but that dried brewers' yeast was able to give good protection in doses of about two ounces daily, and that an extract of yeast free from protein was equally effective.

Recent field studies reëmphasize the importance of nutritional factors in pellagra. In 1932 Drs. H. K. Stiebeling and H. E. Munsell of the Bureau of Home Economics, United States Department of Agriculture, investigated the food supply of 73 South Carolina farm families and its relation to the incidence of pellagra, dividing them into two groups: (a) 44 families in an unsatisfactory economic situation, members of which were suffering from pellagra or in imminent danger of doing so soon; and (b) 29 families whose economic condition indicated that they could without aid maintain themselves in a better state of nutrition than the other group. To each of the families in the first group some kind of pellagra-preventing food was furnished, dried or evaporated milk, wheat germ, cured lean pork, canned tomatoes, or pure dry yeast being chosen for the purpose. Periodic examination of these 44 families for pellagra revealed that the incidence and severity of the disease were less than in former years and much less than in unaided families of similar resources during the period under observation. The families successful in warding off pellagra used diets more abundant in every respect, furnishing on the average two and one quarter cups of milk per person per day, about three ounces of fruit and succulent vegetables, and about three ounces of lean meat. The families in which over a parallel period pellagra occurred used on the average

[1] Goldberger, J., and Wheeler, G. A. *The Experimental Production of Pellagra in Human Subjects by Means of Diet.* Hygienic Laboratory, United States Public Health Service, Bulletin No. 120 (1920).

less than one fifth of a cup of milk, less than three ounces of vegetables and fruits, and less than three ounces of lean meat, fish, and eggs together, per person per day.

One is reminded of Goldberger's statement regarding possible benefit to pellagrins from a change to the country: "Practically, so far as pellagra is concerned, all the benefits of a 'change of climate' may be had at home at the cost of half a gallon of milk or half a pound of stew beef a day." [1]

The other field study was made by Dr. M. R. Sandels and Miss E. Grady of the Florida State College for Women in Leon County, Florida. Careful comparisons of the diet of 16 pellagrous and 13 nonpellagrous families were made at four seasons of the year. Recurrence of pellagra occurred most frequently in March and April, before the increased food supply of the spring was available. The most important difference in the dietaries was in the amount of milk, the mean per cent of the total calories from this food being in each of the four periods from two to three times as high in the nonpellagrous as in the pellagrous families. Differences in the succulent vegetables were also outstanding, especially in the winter, when the nonpellagrous families averaged 8.8 ounces per man per day while the pellagrous families had only two ounces per man per day. Such vegetables are relatively rich in vitamin G as compared with roots and tubers or with fruits.

Doctors G. A. Wheeler and W. H. Sebrell of the United States Public Health Service report that under institutional conditions, where the diet can be controlled, the problem of pellagra can be eliminated. They say, "By a few simple and comparatively inexpensive additions to the daily menu, one state institution for the insane, the largest in the South and second largest in the country, has reduced the annual death rate from pellagra from 6.2 per cent of all inmates to as low as 0.1 per cent, this in spite of the fact that during the same time deaths from this cause for the state at large increased

[1] Goldberger, J. "Pellagra: Its Nature and Prevention." *United States Public Health Reports*, Reprint No. 461, pages 481–488 (1918).

almost 100 per cent. . . . Except under extremely reduced resources, its conspicuous presence in any community in which the diet is subject to regulation by central authority can no longer be justified." And further, regarding the pellagrous districts in the country at large they make this significant statement: "In looking for cases of pellagra, the home surrounded by evidence of a good garden, or a cow or two, a few pigs and some poultry may as well be passed up, for the chances are less than one in a thousand that pellagra will be found. On the other hand, the home surrounded only by last year's cotton patch will always bear watching." [1]

Pellagra appears to be more easily prevented than cured by dietary measures. But that it can be cured is now conclusively proved. Doctor T. D. Spies,[2] at the Lakeside Hospital in Cleveland, Ohio, has been able to reduce the mortality of cases of pellagra coming to the hospital to less than 5 per cent within the last few years, whereas formerly most of them succumbed to the disease. The cure involves more than ordinary care, however. The patients are given a diet furnishing 4,000 calories per day, supplemented with from 75 to 100 grams of brewers' yeast or wheat germ daily, in doses of 10 to 20 grams served in iced milk or eggnog several times a day. In addition, injections of liver extract are also given from three to five times daily. With this treatment and adequate rest, cures formerly regarded as impossible are now achieved.

What the essential substance or substances in the brewers' yeast, wheat germ, and liver, or in the various foods which have been found to have pellagra-preventing power may be is still unknown. As soon as pure vitamin G (riboflavin) was available, all haste was made to see whether this is the essential factor. But experiments on dogs suffering from experimental blacktongue, which resembles human pellagra more closely than any other condition experimentally pro-

[1] Wheeler, G. A., and Sebrell, W. H. "The Control of Pellagra." *Journal of the American Medical Association*, Vol. 99, page 95 (1932).

[2] Spies, T. D. "Medical Treatment of Early Pellagra." *Journal of the American Medical Association*, Vol. 105, page 1028 (1935).

duced in an animal and is preventable and curable by yeast, wheat germ, and other pellagra-preventive foods, was not influenced at all by vitamin G.[1] Also administration of the vitamin to a number of cases of human pellagra has left little doubt that vitamin G alone is not capable of inducing a cure.

Vitamin H (B_6)

Skin symptoms which are pellagra-like in character can be induced not only in dogs but also in rats and chicks. However, the conditions under which this can be done are not uniform for the three species nor is the character of the dermatitis always the same. The acquisition of pure vitamin B (B_1) and pure vitamin G (riboflavin) gives the investigator of today a great advantage in his efforts to find all the members of the vitamin B complex. Already it is clear that there are several other substances to be isolated and identified. Something more is essential for growth and the factor which cures rat dermatosis is not identical with that which cures chick dermatitis nor with that which cures blacktongue in dogs.

Out of the confusion one factor has emerged quite clearly. It is variously designated as vitamin H, factor Y, and vitamin B_6. For the present, until its chemical nature is known, vitamin H seems a convenient designation. It has been extracted and concentrated to 100 times its original strength by Booher and shown to be essential for growth and for the health of the skin in the rat. This function it shares with vitamin G but in a different way. Lack of vitamin G causes loss of fur and scaliness as outstanding symptoms, while lack of vitamin H causes acute inflammation of the paws, nose, and ears.[2]

At least one other factor besides vitamin H is already known to exist and its relation to human pellagra is being

[1] Sebrell, W. H., Hunt, J. D., and Onstott, R. N. "Lactoflavin in the Treatment of Canine Blacktongue." *United States Public Health Reports*, Vol. 52, page 235 (1937).

[2] For a discussion of these different forms of dermatitis see Richardson, L. R., and Hogan, A. G. *Skin Lesions in the Rat Associated with the Vitamin B Complex.*" Missouri Agricultural Experiment Station, Research Bulletin No. 241 (1936).

investigated. It is reasonable to think that in time the resolution of the vitamin B complex will furnish the key to this nutritional deficiency just as other vitamin research has already provided the means of preventing rickets and scurvy and beriberi.

Vitamin H is abundant in cereals, which are relatively poor in vitamin G. Here again the combination of whole grain cereals with milk, which is rich in vitamin G, has a nutritional advantage comparable to the supplementary value between the proteins of the two types of food; and to that between the iron and copper of the cereal and the calcium of the milk, which is so favorable for iron utilization.

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CHAPTER XVI

CONTRIBUTIONS TO THE DIET MADE BY VARIOUS TYPES OF FOOD MATERIALS

In previous chapters we have considered the essentials of an adequate diet and have found that they may be stated under five headings:

(1) Energy to meet the daily expenditure; with surplus for storage only when actually needed for growth or to build up an underweight adult.

(2) Protein in sufficient quantity to replace daily nitrogen loss, and to supply a liberal and complete assortment of indispensable amino acids, especially during growth.

(3) Ash constituents or mineral elements of many kinds, each with its own special function for which no other can be substituted, and all so related to the regulation of life processes as a whole that any failure of an adequate supply is likely to bring disaster, especially during growth.

(4) Vitamins, of which six are definitely recognized, serving as regulators of metabolism and controlling the processes involved in maintenance, growth, and reproduction.

(5) Water, not only an important constituent of the body, but the carrier of food to the tissues and waste away from them, and otherwise important in the regulation of body processes.

These dietary essentials may be conveniently summarized according to their main functions in the following way:

(1) Food as a source of energy or fuel for the body machine

Carbohydrates
Fats
Proteins

(2) Food as a source of material for the development and maintenance of body structure

Proteins
Mineral Elements
Water

(3) Food as a means of coördinating and otherwise regulating body processes

Mineral Elements
Vitamins
Water

What Relation Has a Food to the Diet?

Having learned what types of nutriment are needed to keep the body in prime working condition, our next task is to consider what relationship individual food materials have to the diet as a whole. Few foods consist, as does cane sugar, of a single chemical substance. The novice in nutrition is like a person who has never seen a watch: when he looks at it for the first time, all he observes is a shiny case with a glass front covering a dial bearing numbers from one to twelve, and hands which revolve upon it. How different the mental picture of the watchmaker, who with his mind's eye looks through the metal case as if it were transparent and beholds delicate wheels, jewels, screws, and springs, all related to each other and harmoniously contributing to the beautifully coördinated movement of the whole! So it is with any article of food. To a person who has not studied nutrition, an orange is a bright-colored, fragrant globe inside of which are neatly packed sections yielding a delicious juicy pulp. It is just something good to eat. So are cake and pie and chocolate creams. But to the one who has learned to think in terms of nutritive value, an orange is a food shop. First, there is water—much of it; it constitutes nearly nine tenths of the weight of the peeled fruit. Then there is sugar, amounting to one tenth of the edible portion; a mere "sample" of protein; scarcely a trace of fat; a galaxy of mineral

elements, including calcium, phosphorus, sulfur, iron, sodium, potassium, etc.; and lastly, vitamins A, B, C, and G.

Is an orange like a potato? Who would think so, to see or taste them? Yet they have much in common. The potato contains nearly as much water as the orange. It has starch where the orange has sugar, but these are both carbohydrates, serving interchangeably as body fuel. Protein is only slightly more plentiful in the potato, and fat is found as a mere trace in both. The same mineral elements and vitamins may be found, though in different proportions.

If we set out to eat the same number of calories from oranges as from potatoes we may make some interesting discoveries. Very likely we shall be able to eat day after day, without any digestive discomfort, more potatoes than oranges. The fact that oranges are acid and potatoes not may make some difference to our stomachs, but once safely through the digestive tract even the difference in acidity disappears, for the acid of the orange will be quickly burned away, and the two foods will be quite similar in their effect upon the blood.

In the course of such an adventure in eating, it may be borne in upon us that we do not relish the more pronounced acid-sweet flavor of orange along with all sorts of other foods. A plate of meat, orange, and tomato may not seem quite as satisfactory as the more familiar meat, potato, and tomato. Again, if we live where oranges cannot be plucked off the trees, but have to be paid for at a rate to cover the vicissitudes of shipping long distances, we may find it a better economic policy to eat more potatoes than oranges, regardless of our personal preference.

Neither food will furnish adequate protein, so we shall not be safe in limiting ourselves to these two foods, no matter how much we like them. Moreover, the amounts necessary to furnish enough calories might prove something of a tax on appetite if not on digestion, as it would take in the neighborhood of three dozen medium oranges or two dozen medium potatoes for a rather sedentary man for a day; and

then the oranges would not furnish enough iron nor the potatoes enough calcium nor either enough of vitamins A, D, or G. At last we should be driven to other foods for the compounding of a ration ideal in all respects.

Race Experience Does Not Insure Good Nutrition

Experience has taught the human race a great deal of practical value about diet but it is no guarantee of an ideal one. Some people with no scientific knowledge of nutrition are so situated as to be well nourished on their natural diet. McCarrison cites certain isolated peoples in the Himalayas, whom he found remarkably vigorous, although living on what would seem to be a much restricted diet. "For nine years of my professional life," he says, "my duties lay in a remote part of the Himalayas, where there are located several isolated races, far removed from the refinement of civilization. Certain of these races are of magnificent physique, preserving until late in life the characters of youth; they are unusually fertile and long lived, and endowed with nervous systems of notable stability. Their longevity and fertility were, in the case of one of them, matters of such concern to the ruling chief that he took me to task for what he considered my ridiculous eagerness to prolong the lives of the ancients of his people, among whom were many of my patients. The operation for senile cataract appeared to him a waste of my economic opportunities, and he tentatively suggested instead the introduction of some form of lethal chamber designed to remove from his realms those, who by reason of their age and infirmity were no longer of use to the community." [1] These people live on a very frugal diet, consisting of apricots which they sun dry for winter use, vegetables, and goat's milk; goats are the only live stock and while butter is made from the milk, goat's meat is eaten only on feast days.

Mellanby describes another isolated group on the Island

[1] McCarrison, Robert. "Faulty Food in Relation to Gastro-Intestinal Disorders." *Journal of the American Medical Association*, Vol. 78, page 1 (1922).

of Lewis in the New Hebrides, whose houses are unsanitary, being windowless and full of smoke, and whose children get comparatively little sunlight; yet the death rate of their infants is very low and rickets practically unknown. Their diet consists mainly of milk, oatmeal, potatoes, turnips, and fish. A staple article of diet is cod's head stuffed with a mixture of oatmeal, milk, and cod livers, a diet which would seem very limited to an average American, yet has proven capable of a great saving of infant lives over that of English cities, where another type of limited diet appears, chiefly bread, jam, and tea. Here undernutrition and rickets and a high infant death rate bear testimony to the utter inadequacy of the diet. Some people may be so situated by nature that their diet happens to be adequate, but many others are far from attaining the vigor they might have if their foods were selected with more regard to their nutritive values.

Another interesting study of the relationship between man's natural diet and his physical status has been brought to light by Drs. J. B. Orr and J. L. Gilks, of the Rowett Research Institute, Aberdeen, Scotland. Two African tribes living side by side have very different dietary customs. The Masai, a pastoral people whose sole occupation is tending their herds, live largely on meat, milk, and blood drawn from the living animal after puncturing the jugular vein with an arrow. Various roots and barks are used for "teas," taken with boiled meat or milk. The pregnant women are sent into the bush to eat berries.

The Akikuyu subsist chiefly on cereals, tubers, plants, legumes, and green leaves. Large herds of goats are used as currency, not as a source of milk and meat. The men confine themselves chiefly to maize, sweet potatoes, or other cereals and tubers. Young children of both sexes up to the age of five years are given edible earths from salt licks and the ashes of certain swamp plants. The source of supply of one of these earths with an especially high calcium content was at one time in the Masai country. The Akikuyu were then

in the habit of making raids and fighting for this salt. They say their cattle were fatter, bred better, and were more resistant to disease when they had a supply of "Gitirikani earth." The girls continue to use these special sources of minerals through adult life and the women have virtually a monopoly of some kinds of green leaves also remarkably rich in calcium. A certain type of millet about 16 times as rich in calcium as ordinary millets is reserved for them during pregnancy and lactation. This is said to improve the milk flow. The Akikuyu man's diet is exceedingly low in calcium and even when it is supplemented for children with the edible earths and plant ashes it is not adequate for their best growth. During the first month of life the Akikuyu infants are only about half a pound lighter than English babies. For ten months thereafter they grow at about the same rate; after that the Akikuyu grow much more slowly and at 30 months are about 8 pounds lighter than the English. The full-grown Masai male is on the average 5 inches taller and 23 pounds heavier than the full-grown Akikuyu, and his muscular strength is 50 per cent greater. Among the Akikuyu, deformities of the bones, dental caries, spongy gums, anemia, pulmonary diseases, tropical ulcer, and other diseases fostered by poor nutrition were much more prevalent than among their neighbors with a better diet. A study of the children up to 8 years of age showed that while the general physical condition of the Masai boys and girls was rated as "very good" in over 60 per cent of the cases there were only 7 per cent of the Akikuyu boys and 29 per cent of the girls so rated. The diet of the Akikuyu affords striking evidence that race experience does not always lead to the best dietary practices. The calcium obtained by this tribe in too small amounts and with difficulty from the plant ashes and earths is easily secured by their neighbors from milk, with the added advantage that it is more efficiently utilized. The value of a better diet is also shown in the better health of the women and girls as compared with that of the men and boys. In their physical examination only

18 per cent of the girls under 8 years of age were judged "Poor, Bad, or Very Bad"; 44 per cent of the boys were so rated.[1]

While America is still the land of opportunity, and food is sufficiently plentiful and varied to prevent general outbreaks of deficiency diseases, we have to face the fact that the nutritional state of our American school children is far from ideal; our draft records revealed a low state of vigor in case of many of our young men; and the increase of pellagra in our southern states, a disease in which diet must be reckoned a significant factor, bears witness to the need of intelligence in food consumption. It should be a part of every child's education to learn what sort of contributions the different kinds of food material make to this composite thing which we call diet, and to understand that a diet is something to be built, like a house; that just as an architect might specify stone for foundations, tile and stucco for walls, wood for interior finish, glass for windows, slate for roof, wire for electric lighting, brass for door knobs, each in quantities to suit his plan, so we must each have a plan for our diet which shall free us from the dangers of "hit and miss" eating.

Nutritive Values Expressed as Shares of the Day's Requirement

We cannot discern these properties of food without the help of the chemist. Through the work of Atwater and later chemists, we have extensive tables, giving the results of hundreds of thousands of analyses of food materials for protein, fat, carbohydrate, water, and ash (without regard to the various elements found in it). Sherman has provided tables embodying our best knowledge of the ash constituents, and Daniel and Munsell have collected available information as to the value of many foods as sources of the vitamins. All of these sources have been used in preparing Table I of the Appendix.

[1] Orr, J. B., and Gilks, J. L. *Studies of Nutrition: The Physique and Health of Two African Tribes.* Medical Research Council, Special Report Series, No. 155. His Majesty's Stationery Office, London (1931).

To the beginner these tables seem somewhat confusing from the multiplicity of figures for so many dietary factors, but it is possible for practical purposes to state the nutritive values of foods in quite a simple way.

The feasibility of thinking of the energy values of foods in terms of 100 calorie portions has already been stressed in Chapter II. It is customary, when desiring to represent the daily energy requirement of the average man by a single figure, to use 3,000 calories. Each 100 calories would then be $\frac{1}{30}$ of the day's requirement.

Let us now think of a diet requiring 3,000 calories as made up of 30 such portions. As we have already seen, the other allowances here used for the average man may be stated as follows:

Protein, 10 per cent of the total calories or 2.5 grams per 100 calories
Calcium, 0.67 gram or 0.023 gram per 100 calories
Phosphorus, 1.32 grams or 0.044 gram per 100 calories
Iron, 0.015 gram or 0.0005 gram per 100 calories
Vitamin A—3,000 units per day
Vitamin B—300 units per day
Vitamin C—60 units per day
Vitamin G—600 units per day

Standards for vitamins are tentative, pending further studies of requirements but are believed to be ample for the normal adult. For discussion see the section on Requirement under each vitamin.

In an adequate diet we may think of each 100 calories as constituting a cross section of the day's ration and carrying its own quota of each of the above mentioned substances. We may then call each $\frac{1}{30}$ of the day's requirement a share.

One share of energy	=	100	calories
One share of protein	=	2.5	grams
One share of calcium	=	0.023	gram
One share of phosphorus	=	0.044	gram
One share of iron	=	0.0005	gram
One share of vitamin A	=	100	units
One share of vitamin B	=	10	units
One share of vitamin C	=	2	units
One share of vitamin G	=	20	units

Having established these standard values for one share of each dietary essential, it is a simple matter to determine the number of shares contributed by any food whose chemical composition is known, as the following calculation of share values for an orange will show. Choosing one large enough to yield 100 calories, the actual weight of edible material will be 7.2 ounces. The amount of each nutrient and its share value will be as follows:

100 calories	÷	100	=	1.0 calorie share
1.84 grams of protein	÷	2.5	=	0.7 protein share
0.053 gram of calcium	÷	0.023	=	2.3 calcium shares
0.041 gram of phosphorus	÷	0.044	=	0.9 phosphorus share
0.00106 gram of iron	÷	0.0005	=	2.1 iron shares
126 vitamin A units	÷	100	=	1.3 vitamin A shares
145 vitamin B units	÷	10	=	14.5 vitamin B shares
118 vitamin C units	÷	2	=	59.0 vitamin C shares
61 vitamin G units	÷	20	=	3.1 vitamin G shares

It will not be necessary to make such calculations hereafter as the share values for a large number of common foods will be found in Table I of the Appendix. It will be noted that using shares greatly simplifies the calculations of food values. It is much easier to find the iron content of two oranges by observing that it will be 2×2.1 iron shares than by multiplying 0.00106 gram by 2. Whenever the actual weight of iron needs to be known, the total number of shares has only to be multiplied by the standard value of one share of iron, 0.0005 gram.

The contributions which different foods make to the diet are more readily appreciated when presented in graphic form. In Fig. 99 are shown share values for an orange and a potato. The bars from left to right, representing the various dietary essentials, are in this and in succeeding figures given in the order listed in the legend, and the height of each bar corresponds to the share value listed for that essential. Across the bar representing vitamin C in the orange 4 stripes will be noted; these indicate that its full length would be 5 times as much if space permitted. This device is used whenever the number of shares exceeds 12. In making such

graphs with colored crayons on cross section paper where each square represents one share, the bars can easily be widened to include as many squares as may be necessary, with more striking effect.[1]

For Fig. 99 two food portions of the same energy value have been selected for consideration. Comparing their contributions of protein, it will be observed that the orange cannot take care of itself, much less contribute any protein to make up for the deficiencies of other foods. The potato on the other hand has such a proportion of protein to total calories as should be found in an adequate diet, i. e., at least one protein share for every calorie share. Experimental work has shown that protein needs of adults, both animals and men, can be met by potato protein only, but that it will not support growth unless supplemented by some complete protein which makes good certain amino acid deficiencies. Fig. 100 shows the weight record of young rats whose sole source of protein for many weeks was the potato. As the potato protein is easily supplemented with that of milk, eggs, or meat, it can be counted at its full value in a mixed diet. The protein of oranges, playing so insignificant a rôle in the diet, has not been similarly investigated.

By reference to Fig. 99 again, it will be noted that the orange is about four times as rich in calcium as the potato but less rich in phosphorus. By combining the two, the deficiencies of one will be made good by the other.

As sources of iron, the two are about equal, each having as much as one share per 100 calories to contribute to make good the iron deficiency of some other food. But it would require 15 such oranges or potatoes as these to furnish the 30 shares set as the standard for an average man requiring 3,000 calories.

Neither food is a good source of vitamin A. If the orange and potato be combined, the result would still be inadequacy of this vitamin. Both are good sources of vitamin B,

[1] A set of charts giving individual portions of many common foods with their share graphs may be obtained from the Philadelphia Dairy Council, Philadelphia, Pa.

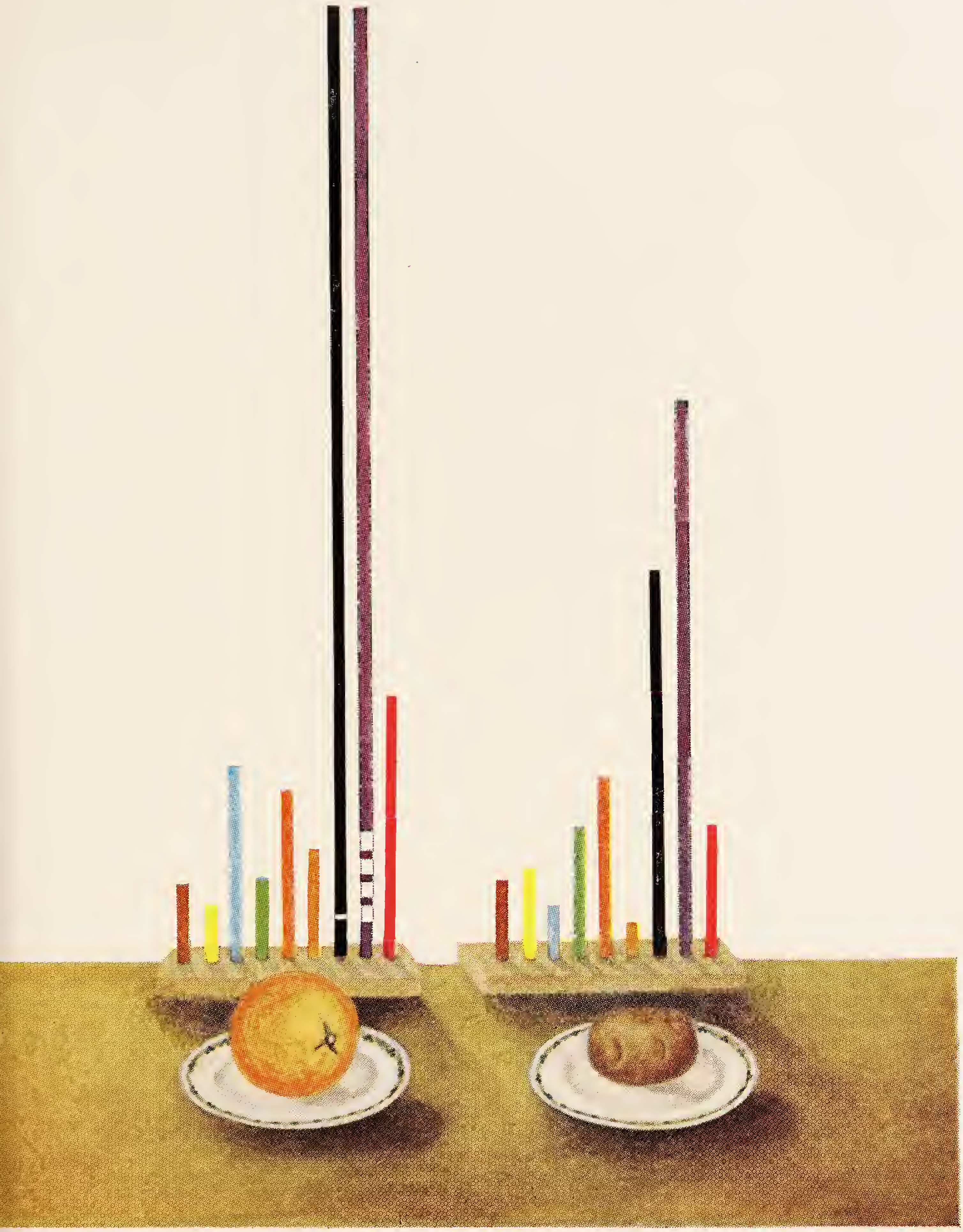

Fig. 99.—A Comparison of the Shares Contributed to an Adequate Diet by an Orange and by a Potato.

	Orange Shares	Potato Shares
Energy	1.0	1.0
Protein	0.7	1.1
Calcium	2.3	0.6
Phosphorus	0.9	1.5
Iron	2.1	2.2
Vitamin A	1.3	0.3
Vitamin B	14.5	4.8
Vitamin C	59.0	6.5 (cooked)
Vitamin G	3.1	1.5

but the orange furnishes about three times as much as the potato. The outstanding contribution of vitamin C made by the orange may be seen at a glance. It will furnish twice as much as is required to meet the standard set for an average

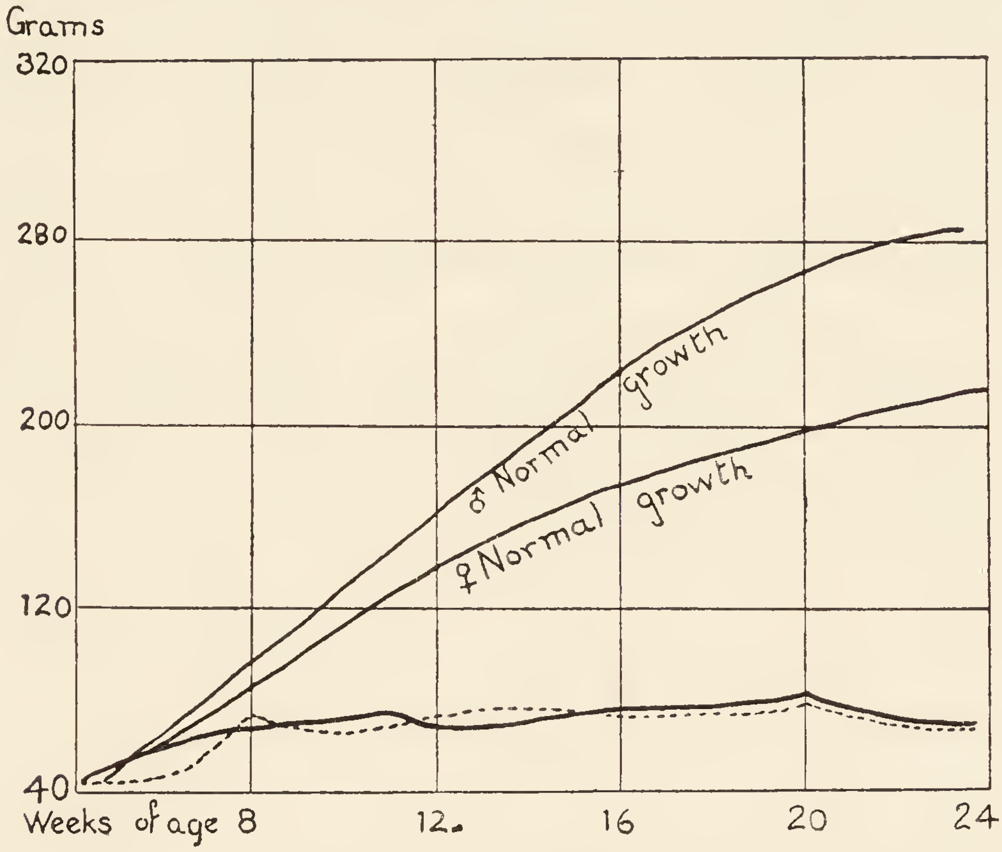

FIG. 100.—Growth of two young rats placed at the age of 4 weeks on a diet in which the protein was liberal in quantity but was derived entirely from the white potato. In 20 weeks they had attained no greater weight than they should have had at the age of 8 weeks.

adult man. The potato, while furnishing less per 100 calories may be eaten regularly in larger amounts, and so make a very substantial contribution to the total vitamin C of the diet. Neither food is an important source of vitamin G.

Foods Grouped According to Nutritive Value

It would be far beyond the scope of this book to discuss a large number of individual foods in the same detail as the orange and potato but, fortunately, many foods are quite similar in their chemical composition and nutritive properties and such we may group together, leaving for further study, with the help of the tables to which reference has already been made and to books like Sherman's *Food Products*, the individual differences among members of the groups.

(1) **Milk** contains the greatest assortment of nutritive substances of all single food materials, and constitutes the foundation upon which an adequate diet can most safely and most easily be constructed.

(2) **The grains** give us primarily sources of energy, and secondarily of protein—not always adequate by itself, but when properly supplemented, of great practical value. Only by special selection does this class of foodstuffs become important for mineral constituents or vitamins. Their most significant vitamin contribution is vitamin B, present in the germ and less richly in the bran. They lack vitamins A and C and have relatively small amounts of vitamin G.

(3) **Vegetables and fruits** are of greatest significance for their mineral constituents and vitamins. Both are irregularly distributed, but if such foods are taken in large enough quantities and embrace a wide range of varieties, there is a good chance of safety, provided certain ones known to be rich in each of the essentials are included. Only certain members of the group are good sources of calories, and still fewer of proteins.

(4) **Eggs, cheese, nuts, meat, fish, fowl, game, etc.,** are of prime significance for their yield of proteins of excellent quality. Most members of this group, with the exception of very lean meats, are also good sources of energy because of the fat as well as the proteins which they provide. Meats and eggs are good sources of iron; and meats, eggs, and cheese of vitamin G. The yield of other minerals and vitamins varies with the different members of the group.

(5) **Fats** are primarily sources of calories in concentrated form. In certain cases they are also carriers of vitamins A and D.

(6) **Sugars,** like fats, are sources of calories. Pure sugars contribute nothing else. A few foods containing sugar in high concentration make other contributions of some significance.

In the following pages the nutritive values of these various food groups will be discussed in more detail.

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CHAPTER XVII

MILK

In 1912 Hopkins published the now classic curves shown in Fig. 53, illustrating the effect on a rat's growth of adding to a ration compounded from purified food materials less than one third of a teaspoonful of milk per day.

From that time to the present, evidence has continued to accumulate regarding the unique place of milk in nutrition. Osborne and Mendel found that milk deprived of its protein and fat enabled them to keep animals alive that otherwise would have died, and that milk proteins would promote growth when some others would not. Then vitamins A and B were discovered in milk, and Sherman and Hawley's demonstration of the superiority of milk as a source of calcium drew from the editor of the *Journal of the American Medical Association* this comment: "The dietary rule of a quart of milk each day for every child is much more than a precept based on individual opinions or drawn by analogy from the results of feeding experiments with lower animals; it now rests on scientific evidence obtained by extensive and intensive experiments directly upon the children themselves." Finally laboratory research has led to the discovery of vitamin G, another factor in the maintenance of that superior state of nutrition which McCollum has called "the preservation of the characteristics of youth," present in milk to a degree which makes it an admirable complement to the cereals so generally rather deficient in this vitamin.

The dependability of milk as a source of many of the essentials of normal nutrition has been demonstrated on a grand scale in the laboratory by Sherman and his associates. On a diet consisting of one sixth part dried whole milk and five sixths ground whole wheat, certain rat families have

prospered through more than 40 generations. Yet increasing the quantity of the milk in a diet of such evident efficiency has brought greater well-being. An increase in the proportion of milk from one sixth to one third has resulted in more rapid growth and greater vitality at all ages. These results have been tested on large numbers of cases and make it quite clear that, as Sherman says, "A longer lease of healthier life will follow an improvement in the dietary of the individual, or the food supply of the community, even where the original dietary was adequate according to current standards." [1]

The value of milk in improving diets chosen "in good faith and with the best of intentions" and supposed to fulfill all the needs of those for whom it was provided is admirably shown in a four-year experiment in an institution for poor English boys, reported by Dr. H. C. Corry Mann in 1926. Three cottages, housing boys from six to eleven years of age, were set apart for the dietary study. One group received the regular diet of the institution, six others received supplementary food, as follows: (1) a pint of milk daily, (2) sugar equivalent in calorie value to the pint of milk, (3) New Zealand butter from grass-fed cows to give the same number of calories as the milk, (4) vegetable margarine equivalent to the butter, (5) edible casein furnishing only 65 extra calories, (6) three quarters of an ounce daily of fresh water cress. The group on the regular diet gained during the four-year period an average per year of 3.85 pounds and 1.84 inches. Extra protein in the form of casein made practically no difference in weight or height. Extra calories in the form of sugar or margarine made no difference in height and increased weight only a very little, the water cress and butter made a slightly better showing, but the milk group gained 6.98 pounds and 2.63 inches. Doctor Mann, at the conclusion of this study, said, "It is startling to learn, as we now do, for instance, that the addi-

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 4th edition, page 534. The Macmillan Co. (1932).

tion of one pint of milk a day to a diet which by itself satisfied the appetite of growing boys fed upon it could convert an average annual gain of weight of 3.85 pounds per boy into one of 6.98 pounds, and an annual average increase of height from 1.84 inches to 2.63 inches. This unmistakable betterment in nutrition was proved by trial to be due, not to the relatively small increase in the fuel value of the dietary, nor to the extra protein supplied in the milk, but rather to more specific qualities of milk as a food." [1]

This work led the Department of Health for Scotland to undertake a series of extensive studies of the influence of milk consumption on the growth of school children in the years 1927–30, involving more than 12,000 children who were fed milk daily at school as a supplement to their regular fare, and about an equal number not given any supplementary food who served as controls. The results amply substantiated Mann's findings, even when only three quarters of a pint of milk was furnished each child for four months. The report for 1930, of a study of 20,000 children five to twelve years old in Lanarkshire, 10,000 of whom had the milk supplement, concludes with these significant words: "The results, read along with the results of the previous Scottish test, are conclusive on the main issue. They demonstrate that the addition of milk to the diet of children has a striking effect in improving physique and general health and increasing mental alertness. They suggest also that, apart from its own food value, milk enables the other constituents of the ordinary diet to be fully utilized as growth factors. . . . The results give a special significance to the new powers conferred on local authorities by the Education (Scotland) Act, 1930. Under the Act, local authorities may make an additional ration of graded milk available to school children. In view of the results of these Scottish tests, it would be difficult to exaggerate the importance of the new powers. Their universal exercise by all

[1] Mann, H. C. Corry. *Diets for Boys During the School Age*, Preface. Medical Research Council, Special Report Series, No. 105. His Majesty's Stationery Office, London (1926).

the local authorities would affect about 800,000 children (the total school population in Scotland), and by improving their physical and mental well-being, would have a powerful influence in improving the quality of the Scottish race." [1]

During the last week or two of the test the various head teachers of the schools were asked to submit in writing their general impressions of the effect upon the children. They speak of "an increase in the bloom of their cheeks and the sleekness of their skins," and one went so far as to say, "in the playground buoyancy and pugnacity are developing to an alarming extent."

These accumulating evidences of the many ways in which milk functions in nutrition have served to emphasize its indispensability in the diet, not only of the child, but also of the adult. No other food can so well serve as the foundation of an adequate diet, because no other reinforces it at so many points. It is for this reason that the term "protective food" is aptly applied to milk.

Energy Value

A quart of milk of average richness yields 675 calories. For the child a year old it will supply from two thirds to three fourths of the total calories required per day; for one five years old, about half the total calories; for a boy or girl ten years old, about one third; and for a city-dwelling man of moderate activity about one fourth. Drinking a single glass at each meal adds nearly 500 calories a day above what would be taken were water the only beverage. Thus it can be readily seen that milk, although nothing to chew, is not insignificant as body fuel.

By measure it takes five eighths of a cup to furnish 100 calories. This is equivalent in energy value to an egg and a third or two yolks; to about two and one fourth ounces of lean round of beef; to one medium potato or one shredded wheat biscuit.

[1] Leighton, G., and McKinlay, P. L. *Milk Consumption and the Growth of School Children*, pages 2 and 3. His Majesty's Stationery Office (1930).

For keeping the calorie intake of growing children up to requirement without disturbing appetite or digestion, milk's only rival is bread or other cereal food.

Protein

A quart of milk yields more than an ounce of pure protein of the highest quality, not only because of an assortment of essential amino acids whose efficiency in promoting growth is unexcelled, but also because under normal conditions it is the most completely digested and absorbed of all food proteins. From every point of view milk is an economical source of protein. It is produced at less expense than proteins of meat or eggs. An acre of cultivated farm land yields crops which when fed to farm animals give the following returns in human food:

Food Produced	Protein, Pounds	Total Calories
Milk	289	711,750
Beef	74	130,000
Mutton	59	137,295
Poultry and eggs	110	148,675

Milk enhances the nutritive value of bread and other cereal proteins by adding those essential amino acids such as lysine and tryptophane in which cereal proteins are relatively poor. Experiments in feeding the lowest amount of protein capable of maintaining nitrogen balance in the adult have shown that less protein is required when milk is practically the sole source than when meat is so used and that proteins derived half from bread and half from milk furnish a mixture which is utilized with the same economy as milk alone.

A calorie share or 100 calorie portion of milk carries nearly two shares of protein, and milk is therefore to be regarded as relatively rich in protein, since only one share is necessary to "balance" the milk itself. The extra share is available to make good the lack in some other food. Thus 100 calories of butter plus 100 calories of milk would give 200 calories

with nearly two shares of protein, and therefore a mixture with a suitable relationship between total calories and protein calories.

Mineral Elements

In milk are found all the different kinds of mineral elements needed in nutrition. Milk ash strongly resembles in its composition the ash of the body of the newborn young to be nourished by it. The table below gives the amount of the various mineral elements in one quart of cow's milk.

Mineral Elements in One Quart of Cow's Milk

	Grams
Calcium	1.151
Magnesium	0.117
Potassium	1.394
Sodium	0.497
Phosphorus	0.907
Chlorine	1.034
Sulfur	0.332
Iron	0.002
Iodine	Present
Copper	"
Manganese	"

Milk is particularly adapted to offset the total lack of minerals in fats and sugars and the serious mineral deficiencies of white flour, hominy, polished rice, and other refined cereal products so widely used in American dietaries. Even where other sources of the mineral elements are included, such as fruits and vegetables, the need for milk remains, since the calcium of the diet depends more upon this than any other food.

The indispensability of milk as a source of calcium for the growing child has already been discussed at length and the desirability of a quart of milk daily to insure the best storage of calcium in the body has been emphasized. Shortage of calcium does not affect growth as quickly as shortage of calories, protein, or some of the vitamins. It is therefore possible, as Sherman has repeatedly pointed out, for a child to grow up "calcium poor." Normal development during growth demands a steady increase in the store of body cal-

cium and this cannot be achieved without a dietary program which insures a liberal daily supply. A quart of milk per day means about 70 per cent more calcium stored than is possible if this allowance is cut down by only half a pint. To substitute vegetables for all of the milk would be practically impossible, even if their calcium could be as well utilized, since about four pounds of such as are relatively high in calcium would be required, and no child could eat so much in a day.

While phosphorus is less likely to be deficient in the dietary than calcium, since it is present in a wide variety of food materials, the necessity of a liberal supply makes the contribution of milk significant. When the calcium requirement is met through the use of milk, we have every reason to believe that the phosphorus requirement will also be covered.

Although milk is not as rich in iron as in calcium or phosphorus, the iron present is in a form which can be most completely absorbed and utilized, and in the diet of the young child a quart will furnish about one fourth of the day's iron requirement.

Since it has been shown that copper is essential to the utilization of iron and since milk is low in copper, it is desirable that the rest of the iron needed come from whole grains and vegetables, which will also furnish copper, thus aiding in a more efficient use of the iron of the milk.

Vitamins

"The cow and the hen consume relatively large quantities of green stuffs, separate the vitamin values from the roughage, and transmit in their milk and eggs a large share of the vitamin value to their young or to the human consumer in a highly assimilable form and accompanied by proteins, fats, and mineral elements all of which are also in forms of exceptionally high nutritive value or efficacy." [1]

A quart of milk yields nearly as much vitamin A as

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 4th edition, page 367. The Macmillan Co. (1926).

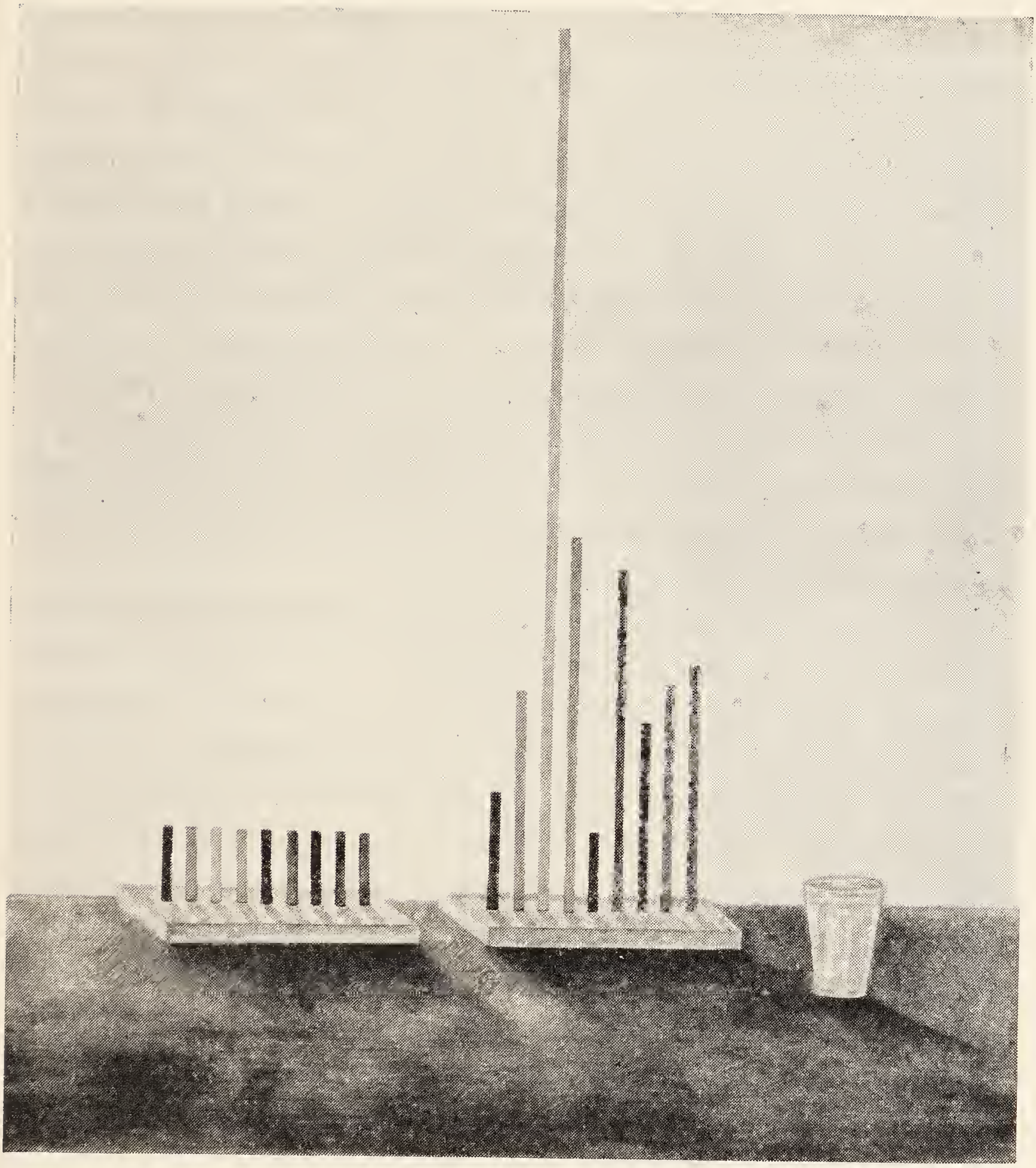

FIG. 101.—Contributions to the Diet Made by a Glass of Milk Compared with a Standard Portion of an Adequate Diet, in Shares.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Standard portion of an adequate diet	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
One glass of raw milk	1.6	3.0	11.8	4.9	1.1	4.8	2.6	3.2	3.5

$1\frac{1}{2}$ cups of unclarified tomato juice or three quarts of orange juice or about two ounces of butter or carrots, or $\frac{1}{2}$ ounce of spinach. From laboratory experiences with diets in which milk furnishes one fourth of the total calories, an amount corresponding to about a quart a day for each child and a pint for each adult in the average family dietary, it appears that this much milk yields sufficient vitamin A for normal growth, and that additions from other foods, such as cream, butter, eggs, and green vegetables may therefore be regarded as an investment for periods of rapid growth in childhood or for special demands such as pregnancy and lactation in the adult, as well as the maintenance of a high resistance of the tissues at all times.

Milk is also relatively rich in vitamin B, one quart being equivalent to $\frac{2}{3}$ cup of orange juice or $1\frac{3}{4}$ cups of tomato juice, to 5 ounces of spinach, or to $\frac{1}{2}$ pound of cabbage. Since the amount of vitamin B required by growing children increases with increasing size, and since the utilization of other foodstuffs has been shown to be promoted by liberal amounts of vitamin B, it seems fortunate that in taking milk for the sake of its protein, calcium, and vitamin A we are also furnishing a considerable portion of the vitamin B needed to cover ordinary daily requirement.

Milk is less dependable as a source of vitamin C than of any other known vitamin. The amount in the fresh raw milk is not very large and varies considerably with the diet of the cow. Pasteurizing milk at 142° to 145° Fahrenheit for one half hour reduces its vitamin C content about 20 per cent. Longer heating or contact with certain metals, especially copper, will destroy more of the vitamin. Standing in a bottle on the doorstep in the sun, one half hour, is enough to destroy most of the vitamin C. The contributions to the diet of one glass of fresh, unheated milk are shown in Fig. 101 (except for vitamin D) in comparison with a standard or 100 calorie portion of an adequate diet. The values for this standard portion are given on page 380.

Milk, having both calcium and phosphorus in liberal

quantities, is indispensable for good bone growth, but it needs supplementing for vitamin D of which it has only a small amount. It is rich in vitamin G compared with most vegetables which have been studied, a quart yielding about as much as $\frac{3}{4}$ pound of spinach or $2\frac{1}{2}$ pounds of lettuce. It is also relatively rich as compared with eggs or lean beef, a quart being equivalent in this vitamin to about $\frac{3}{4}$ pound of the beef or to 4 eggs.

Milk owes its importance in the diet to the fine quality of its proteins and their supplementary value for the cereal proteins; to the completeness of its assortment of mineral elements and the excellent proportions in which they occur; to the high content of calcium and phosphorus, which makes milk almost indispensable for good growth of bones and teeth; to the liberal amounts of vitamins A and G which make a quart of milk a day in a good mixed diet a practical guarantee against deficiency of either; and to a considerable amount of vitamin B. The amount of vitamin C is uncertain, so orange or tomato juice or some other equally good source should be used to supply a liberal amount. It contains but relatively little of vitamin D, so that more of this vitamin should always be obtained from other sources or by use of some form of vitamin D milk.

Evaporated milk is now widely used, because of its convenience and economy, and in case of infants, because of its ease of digestion, due to the fine flaky curds formed in the stomach. The work of Professor Katherine Blunt when at the University of Chicago and of Professor M. M. Kramer and her associates at the Kansas Agricultural College, have shown that the calcium and phosphorus are as well absorbed and utilized as in fresh milk, raw or pasteurized. Vitamins A and D are not materially altered by the processes employed in the evaporation of milk. Vitamin B is likely to be reduced by about one fifth. The destruction of vitamin C is not a serious matter since it is now customary to give infants and children orange juice or some other supplement for this vitamin regularly.

Evaporated milk is pure cow's milk minus about half of its water and is not to be confused with sweetened condensed milk which is preserved by the addition of a large amount of cane sugar.

Powdered milk is made from either whole milk or skim milk. Both are excellent products from the nutritional standpoint, and prepared by modern methods retain all the food values of the original milk, even most of the vitamin C.

Vitamin D milk is a recent market product which offers additional protection against rickets for the infant and young child. Antirachitic properties are successfully imparted to both fresh and evaporated milk by irradiation, by addition of an extract of cod liver oil (oil free), by addition of irradiated ergosterol, or by feeding irradiated yeast to the cow. The amount of vitamin D which can be added to milk by irradiation is limited and such milks usually contain an amount which is close to the minimum for rickets prevention, protection being based on the assumption that at least 24 ounces of milk will be consumed per day by the infant. When a cod liver oil concentrate is added, the task is to determine how much will be desirable, not only to give insurance against rickets for the average healthy infant, but to furnish that more liberal supply which has been found necessary for the best growth. After careful consideration of the experimental evidence, the Council on Foods of the American Medical Association [1] concluded that excellent protection is afforded by milk with 400 units per quart. Milk with added ergosterol is not quite so efficiently used as that from an animal source, but vitamin D is better utilized in milk than when taken any other way. Generally vitamin D in milk costs more per unit than that in cod liver oil, which will at the same time furnish liberal amounts of vitamin A practically free of cost. Even if vitamin D milk is used, the young child should have at least a teaspoonful of cod liver oil daily.

[1] "Vitamin D Milk," a Report Authorized for Publication by the Committee on Foods of the American Medical Association. *Journal of the American Medical Association*, Vol. 106, page 2066; 2150 (1936).

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CHAPTER XVIII

THE FOODS DERIVED FROM GRAINS

Wherever we have agriculture, we have the cultivation of grain. This affords a staple article of diet which can be placed in reserve for seasons of scarcity, and one whose keeping qualities and ease of marketing make it relatively cheap. For half the people of the world rice is said to be the chief article of diet and corn is said to constitute one third of the total intake of southern negroes. In the United States and Great Britain nearly one third of the calories in the diet are derived from cereals in the form of bread.

Seldom is the intact kernel of any grain used as food by man in any considerable amount. It is not easy to eat dry whole grains. From time immemorial they have been ground, crushed, or otherwise treated, to break up or remove the bran coats. With the increase of trade and the shipping and storing of grain foods, there has grown up the practice of removing the germ because it is here that insects love to deposit their eggs, and the result is ruin so far as fitness for human food is concerned. Also the oil of the germ tends to become altered and spoil the flavor. Hence the germ or embryo has been mostly used for the feeding of animals or other purposes.

But since we have come to appreciate the value of vitamin B more attention is being given to the preparation of both bran and germ for human use. Very frequently cereals containing bran are called "whole grain" cereals, when they merely contain more or less bran but not the germ. In case of oatmeal, the greater part of the germ and a considerable part of the bran are to be found in the milled product. White rice (polished) has lost both germ and bran, while brown rice (cured) is free from the husk but retains most of

the bran and germ. Pearl barley and barley flour are devoid of both bran and germ. "New Process" cornmeal has no germ and little bran. Whole wheat flour, graham flour, shredded, puffed, and rolled wheat are practically whole grain, while white flour has neither bran nor germ.

Energy Value

Since the uncooked cereal foods are all very low in moisture content, and have great similarity in chemical composition, they have much the same energy value, approximating 1,650 calories per pound. The weight of a 100 calorie portion (dry) is close to one ounce, although the space occupied by one ounce will differ with the coarseness of the material, from three tablespoonfuls of patent wheat flour to $1\frac{1}{4}$ cups of puffed wheat, or one shredded wheat biscuit. When cooked, there will be variation in weight as well as measure, due to the amount of water absorbed. Thus three tablespoonfuls of grapenuts are equivalent in calories to a cup of cooked oatmeal mush.

Protein

From 8 to 12 per cent of the calories in cereal foods are derived from protein. In their analysis of 224 American dietaries Sherman and Gillett found that grain products contributed 38 per cent of the total calories and 37 per cent of the protein, and in a series of studies made at the University of Maine grain products furnished 40 per cent of the fuel value and 25 per cent of the protein. It is generally safe to assume that in grain products about one share of protein will accompany a share of energy.

We have already seen, in the discussion of protein in Chapter VII, that individual cereal proteins differ in their amino acid assortment, but that several kinds of protein are found in one grain, and the proteins of bran and germ tend to supplement those of the endosperm. Laboratory experimentation has shown that the proteins of wheat, oats, maize, rye, and barley are about equally efficient in pro-

moting and supporting growth. None of them is quite equal in value to an equivalent weight of the complete proteins which we find in milk, eggs, or meat, but all of them can be made highly efficient by combination with relatively small amounts of milk.

The proteins of wheat flour will not support growth as well as those of the whole grain, although very efficiently used in the maintenance of the adult. But if bread be made with milk instead of water, or if breakfast cereals be eaten with milk, the value of the combination may equal the average protein value of an ordinary mixed diet.

Mineral Elements

While there is much similarity in the energy and protein values of cereal foods, including highly refined flour and white bread, there is great diversity in their yield of minerals. Much of this is due to milling, since the outer coats of the grains contain most of the mineral matter. The cereal foods, even when made from the whole grain, are deficient in calcium as the following table shows:

Shares of Calcium in 100 Calorie Portions of Common Cereal Foods

Buckwheat flour	0.1
Cornmeal	0.2
Hominy	0.2
Macaroni	0.3
Oatmeal	0.7
Rice (brown)	0.8
Rice (polished)	0.1
Rye flour	0.2
Shredded wheat	0.5
White bread (water)	0.5
White flour	0.2
Whole wheat bread (water)	0.9
Whole wheat grain	0.4

The whole grains carry more than their own quota of phosphorus, but this, again, may be much reduced by milling. It will be noted that even when milk is used in making wheat bread, only that made with whole wheat does not need supplementing for phosphorus.

Shares of Phosphorus in 100 Calorie Portions of Common Cereal Foods

Buckwheat flour	1.2
Cornmeal	1.0
Hominy	0.5
Macaroni	0.9
Oatmeal	2.2
Rice (brown)	2.2
Rice (polished)	0.6
Rye flour	1.9
Shredded wheat	2.0
White bread (milk)	0.8
White bread (water)	0.8
White flour	0.7
Whole wheat bread (milk)	1.5
Whole wheat bread (water)	1.4
Whole wheat grain	2.0

The contributions to the diet made by polished rice, shredded wheat, rolled oats, and white farina are shown in Fig. 102, and the data represented by the blocks are given below the figure.

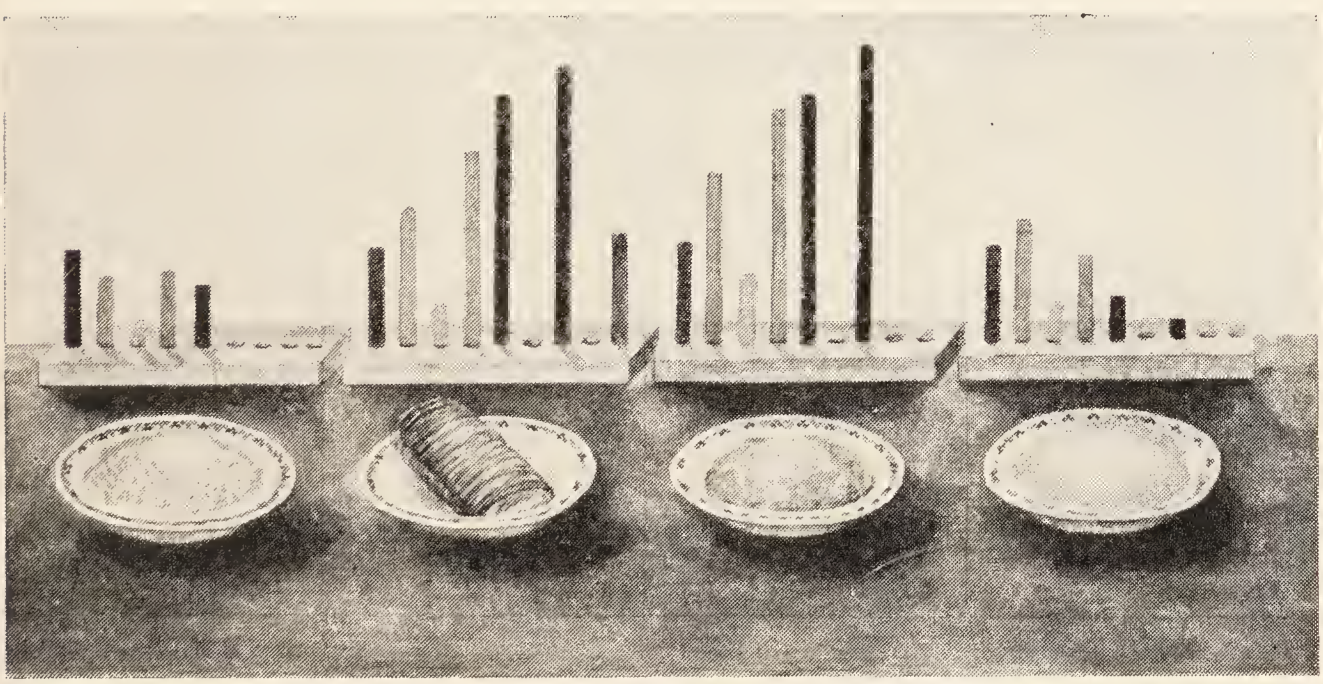

Fig. 102.—Shares Contributed to the Diet by Individual Portions of Polished Rice, Shredded Wheat, Rolled Oats, and White Farina.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Rice, polished, cooked, $\frac{3}{4}$ cup (4.0 oz.)	1.0	0.9	0.1	0.6	0.5	—	—	—	—
Shredded wheat, 1 biscuit (1.0 oz.)	1.0	1.3	0.5	2.0	2.5	—	2.8	—	1.1
Rolled oats, cooked, $\frac{3}{4}$ cup (4.8 oz.)	1.0	1.7	0.7	2.2	2.4	—	3.5	—	+
White farina, cooked, $\frac{3}{4}$ cup (6.0 oz.)	1.0	1.2	0.3	0.8	0.4	—	0.1	—	—

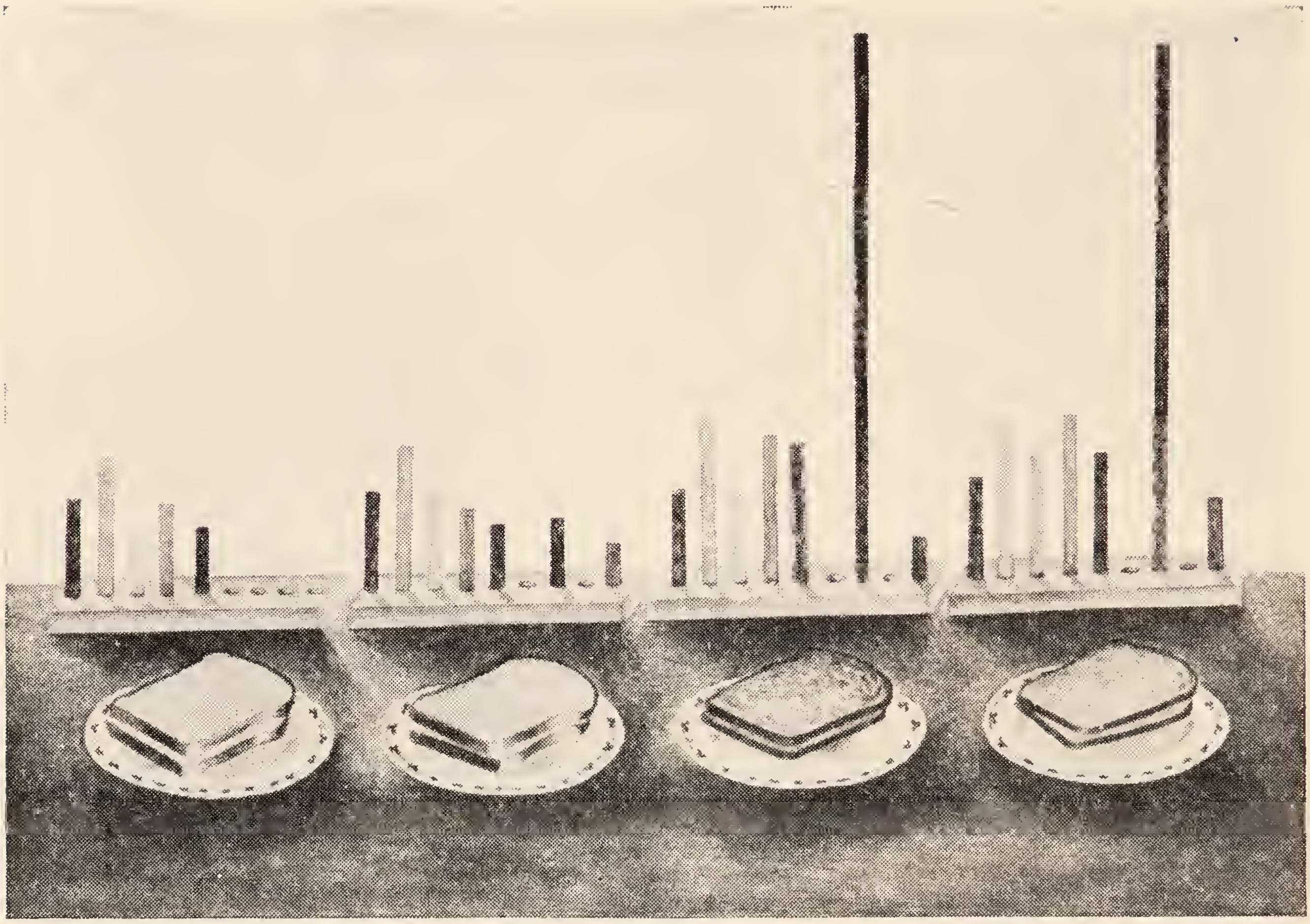

Fig. 103.—Shares Contributed to the Diet by Amounts of Bread Easily Eaten at a Meal.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
White bread, made with water (1.4 oz.)	1.0	1.4	0.5	0.8	0.7	—	—	—	—
White bread, made with milk (1.3 oz.)	1.0	1.4	1.0	0.8	0.6	—	0.4	—	0.5
Whole wheat bread, made with water (1.4 oz.)	1.0	1.6	0.9	1.4	1.3	—	6.1	—	0.8
Whole wheat bread, made with milk (1.2 oz.)	1.0	1.5	1.1	1.5	1.2	—	5.4	—	0.7

Of the mineral elements lost in the manufacture of white flour, iron is the one that can be least well spared. In 92 dietaries analyzed by Sherman cereals contributed one fourth of the total iron. Since the less the money available for food the more dependence there will be on the cereal foods, those yielding iron should be regularly chosen, as they can be made the carriers of this essential element with little or no extra cost. Studies of children's dietaries make it quite evident that no very economical diet for a child can be

liberally supplied with iron without the use of cereal foods (including breadstuffs) which contain it.

The high iron yield of oatmeal and of wheat preparations including bran is clearly shown in the following table:

Shares of Iron in 100 Calorie Portions of Common Cereal Foods

Buckwheat flour	0.7
Cornmeal	0.5
Hominy	0.5
Macaroni	0.7
Oatmeal	2.4
Rice (brown)	1.1
Rice (polished)	0.5
Rye flour	0.9
Shredded wheat	2.5
White bread (milk)	0.6
White bread (water)	0.7
White flour	0.6
Whole wheat bread (milk)	1.2
Whole wheat bread (water)	1.3
Whole wheat grain	2.0

The contributions to the diet made by different types of bread are shown in Fig. 103, and the data represented by the blocks are given in the table below the figure.

Vitamins

Whole grains, like other seeds, are relatively poor in vitamin A, and whatever amount is present is found chiefly in the germ so commonly removed. They are entirely lacking in vitamins C and D and contain relatively little vitamin G. Hence no dependence should be placed on cereals for any of these vitamins.

On the other hand, both germ and bran are excellent sources of vitamin B. The germ is at least five times as rich in this vitamin as the whole grain or bran. Wheat germ is more appreciated as food for human beings since the general need for generous amounts of vitamin B has been shown by laboratory and clinical tests. It may be safely used where the cellulose of bran is objectionable; and is helpful where an especially liberal intake of the vitamin is desired

without a high calorie intake, as in reducing diets. It may easily be added to the diet of growing children in various ways. Rolls containing 50 per cent of wheat germ were successfully used by Dr. A. F. Morgan in her study of the effect of added vitamin B on the growth of school children (see page 263). Several cereal breakfast foods on the market contain added wheat germ. This is an economical and convenient way to increase the vitamin B in the diet. Since milk is rich in vitamin G, which cereals lack, and whole grains are such an excellent source of vitamin B in which milk is not very rich, we have another good reason for saying that the best foundation for an economical diet is a combination of milk and whole grain cereals.

Summary

The cereal foods as a class are primarily sources of energy, valuable for their abundance, economy, ease of digestion, and bland flavor. Since they can be eaten freely by all, they become significant as sources of protein although it is not of such quality or quantity as to permit of their being relied upon as the sole source. When those preparations are selected which include the germ and the bran, the cereal foods, including bread, may make important contributions to the mineral content of the diet (especially iron) and also the vitamin B content.

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CHAPTER XIX

VEGETABLES AND FRUITS

Advances in the science of nutrition have brought into prominence foods which formerly were held in too low esteem. As long as knowledge of nutritive values was limited principally to proteins, fats, and carbohydrates, foods which were not good sources of one or all of these received scant consideration. Such energy-bearing vegetables as dried seeds of legumes, potatoes, and bananas might be assigned a definite place in the diet, but anything as watery as a tomato seemed a misguided choice to one whose main thought was calories, since for the same money twenty times as many might be purchased in the form of oatmeal or other cereal food. But research was steadily progressing in regard to phases of nutrition other than calories and protein, as has been shown in the chapters on mineral elements and vitamins. In 1911 the first edition of Sherman's *Chemistry of Food and Nutrition* was published, giving to students of nutrition quantitative dietary standards for iron, calcium, and phosphorus, along with the first reliable tables of data on the mineral elements in common food materials. Later work has only served to emphasize the importance of mere traces in the body of essential mineral elements such as iodine or copper; and of vitamins protective in amounts so small as to demand a new unit of measurement, a millionth of a gram, called a gamma. In consequence, vegetables and fruits, which are the ultimate sources of the vitamins and the chief conveyors of the minerals of the soil to the animal body, aside from eggs and milk, have assumed a new place in human nutrition, and many people have found improved health and vigor through their freer use.

In addition to their value for nutrients indispensable for

health and growth, vegetables and fruits deserve a place in the diet because of their laxative properties. The human intestinal tract is so constructed that a certain amount of ballast or roughage is needed to keep the muscles in condition and insure prompt elimination of waste. The fibrous framework of leaves, stems, and even some bulbs, tubers, and roots, yields a spongy mass which serves the purpose admirably. Furthermore, vitamin B has been found such an important factor in the normal muscle tone upon which intestinal activity depends, that the laxative property of vegetable fiber is definitely increased by its presence in liberal amounts. Finally, the mineral salts and the mildly acid juices found in many members of the group probably give some additional stimulus to intestinal activity.

Energy Value

Vegetables and fruits vary so greatly in their energy value that no general statement is applicable to all. Reference must be made to tables giving weight or measure for satisfactory information about individual members of this group. Vegetables may be any part of a plant—leaf, stem, bulb, tuber, root, seed or seed pod, blossom or fruit—and like parts tend to similarity in composition. Acid fruits, flowers, leaves, and stems, such as tomato, cauliflower, lettuce, cabbage, asparagus, and celery, are practically negligible so far as calories are concerned. Fleshy roots, bulbs, and tubers, being storage parts of the plant, contain energy-yielding carbohydrates either as starch, as in the white potato; or sugar, as in the carrot; or both, as in the sweet potato. From five to ten ounces of any such vegetable will yield one hundred calories. Seeds are higher in energy value than other storage parts, and when mature and dry resemble the cereal foods, having a fuel value of about 100 calories per ounce.

Among fresh fruits there is also much variability, but many common ones resemble the underground vegetables. It takes almost the same weight of banana as of white

potato to yield 100 calories; about the same of apple as of onion; nearly the same of grapefruit as of carrots; and the same of cranberries as of beets. Some of these relationships are shown in the following table:

A Comparison of Energy Shares (100 Calories) per Pound of Edible Material in Some Fresh Fruits and Vegetables with Those in Cereals and Dried Sweet Fruits

Cereals, Dried and Fat Fruits	Shares	Sweet Fruits and Vegetables	Shares	Fruits and Vegetables with Little Sugar or Starch	Shares
Oats, rolled	18.0	Corn, green	4.7	Currants	2.8
Wheat, flaked	16.3	Peas, green	4.5	Cranberries	2.1
Cornmeal	15.9	Banana	4.5	Lemons	2.0
Rice	15.9	Grapes	3.6	Turnips	1.6
Dates	15.8	Pears	2.9	Kohlrabi	1.6
Raisins	15.6	Apples	2.9	Asparagus	1.2
Figs	14.4	Pineapple	2.6	Spinach	1.1
Prunes	13.7	Oranges	2.2	Tomatoes	0.9
Apricots	12.6	Onions	2.2	Celery	0.9
Avocado	12.0	Beets	2.1	Lettuce	0.8
Olives	5.8	Carrots	2.1	Rhubarb	0.8

With the exception of dried fruits and legumes, which per pound yield nearly as many calories as the cereals, we must regard our common fruits and vegetables as contributing only moderately to the energy value of the diet, although when used freely as is the case with potatoes they may have more significance as sources of calories. The contributions to the diet of medium-sized portions of each of three common fruits, the orange, banana, and apple, are shown in Fig. 104.

Protein

Fresh vegetables and fruits are not large contributors to the total protein of the diet. Fruits seldom carry more than half enough protein to balance their own calories; root vegetables usually yield a protein share for every calorie share, but have little surplus to make good the protein deficiencies in other foods. In this respect they resemble the cereals. Green vegetables are in proportion to their calories surprisingly rich in protein, a 100 calorie portion of collards,

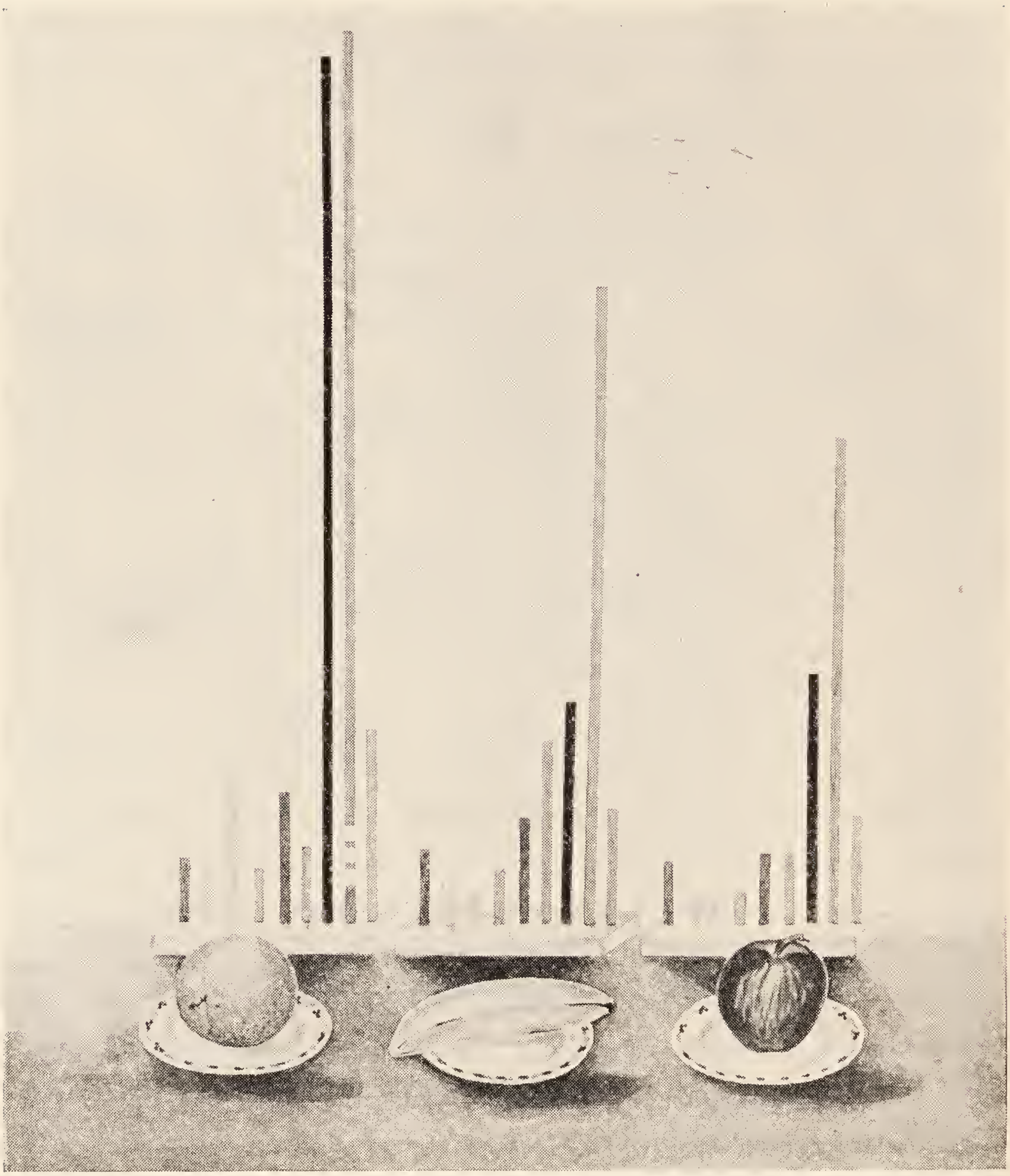

FIG. 104.—Shares Contributed to the Diet by an Orange, a Banana, and an Apple.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Orange, 1 medium	0.8	0.6	1.8	0.7	1.7	1.0	11.6	47.2	2.5
Banana, 1 medium	1.0	0.5	0.4	0.7	1.3	2.4	2.9	8.5	1.5
Apple, 1 medium	0.8	0.2	0.4	0.4	0.9	0.9	3.2	6.4	1.3

escarole, or spinach yielding as many protein shares as one of eggs or buttermilk; and a 100 colorie portion of peas as much protein as one of cheese or lean lamb chops. But in consequence of the fact that one would be likely to eat four or five times as many calories of cheese or egg as of spinach, the total amount of the protein contributed to the diet by green vegetables is very small. The main thing to remember is that they are quite able to take care of themselves so far as quantity of protein is concerned.

Our information regarding the quality of proteins in fresh vegetables is scanty, but the leaf proteins are thought to be, weight for weight, of better quality than seed proteins. Potato protein is adequate for maintenance but not for growth.

Protein in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruits	Shares	Root Vegetables	Shares	Fresh Green Vegetables	Shares	Dried Legumes	Shares
Bananas	0.5	Beets	1.4	Spinach	3.5	Lentils	2.9
Figs, dried	0.5	Turnips	1.4	Brussels sprouts	3.1	Peas, split	2.8
Grapefruit	0.5	Onions	1.3	Peas	2.8	Beans, navy	2.6
Plums	0.5	Rutabagas	1.3	Lettuce	2.7	Cowpeas	2.5
Peaches	0.4	Potatoes	1.1	Chard	2.4	Beans, kidney	2.3
Pears	0.4	Carrots	1.0	String beans	2.2	Beans, Lima	2.1
Apples	0.3	Parsnips	1.0	Peppers	1.6		
Pineapple	0.3						
Prunes, dried	0.3						
Dates	0.2						

The dried legumes have nearly the same proportion of protein to total calories as the green vegetables, but are practically more important sources because of the larger number of calories consumed. To eat 100 calories of navy beans is not generally considered any greater task than to consume 25 calories of string beans. As these two foods have nearly the same amount of protein per 100 calories, the practical result would be 2.6 shares of protein from the navy beans and only 0.6 of a share from the string beans. The quality of legume proteins differs with the species. Navy beans (*Phaseolus vulgaris*) and cowpeas (*Vigna sinensis*)

have proteins which require cooking to develop their full nutritive value, and even then they will not support growth without reinforcement, being deficient in the essential amino acid cystine. Soy beans are complete, but must be cooked to support growth. The proteins of common garden and field peas (*Pisum sativum*) are complete and will support growth without cooking.

Mineral Elements

As sources of mineral elements vegetables are of very great importance. Along with those elements needed in relatively large amounts, such as calcium, phosphorus, and iron, we receive in these foods a number of others, such as iodine, which although present in minute quantities are of real significance, as has already been pointed out in Chapters VIII and IX.

Calcium in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruits	Shares	Root Vegetables	Shares	Leaf and Stem Vegetables	Shares	Dried Legumes	Shares
Figs, dried	2.7	Rutabagas	8.0	Cauliflower	17.4	Beans, navy	1.9
Oranges	2.3	Turnips	7.0	Chard	17.4	Beans, kidney	1.9
Tomatoes	2.1	Carrots	4.4	Celery	17.0	Lentils	1.3
Grapefruit	1.7	Parsnips	4.0	Kale	15.4	Cowpeas	1.3
Cranberries	1.1	Onions	3.6	Cabbage	6.2	Beans, Lima	0.9
Pears	1.0	Beets	2.7	String beans	5.8		
Dates, dried	0.9	Potatoes	0.6	Lettuce	4.4		
Prunes, dried	0.8			Asparagus	3.5		
Raisins	0.7			Brussels sprouts	2.0		
Apples	0.6						
Pineapple	0.6						
Bananas	0.4						

As a source of calcium for growth, milk stands preëminent, but in the diet of the adult, the calcium of vegetables has been found to be well absorbed. Leaf and stem vegetables are generally richer in this element than other vegetables or fruits, but carrots among root vegetables, oranges, figs, and strawberries among fruits yield enough to teach us that it is worth while to learn as much as possible about individual

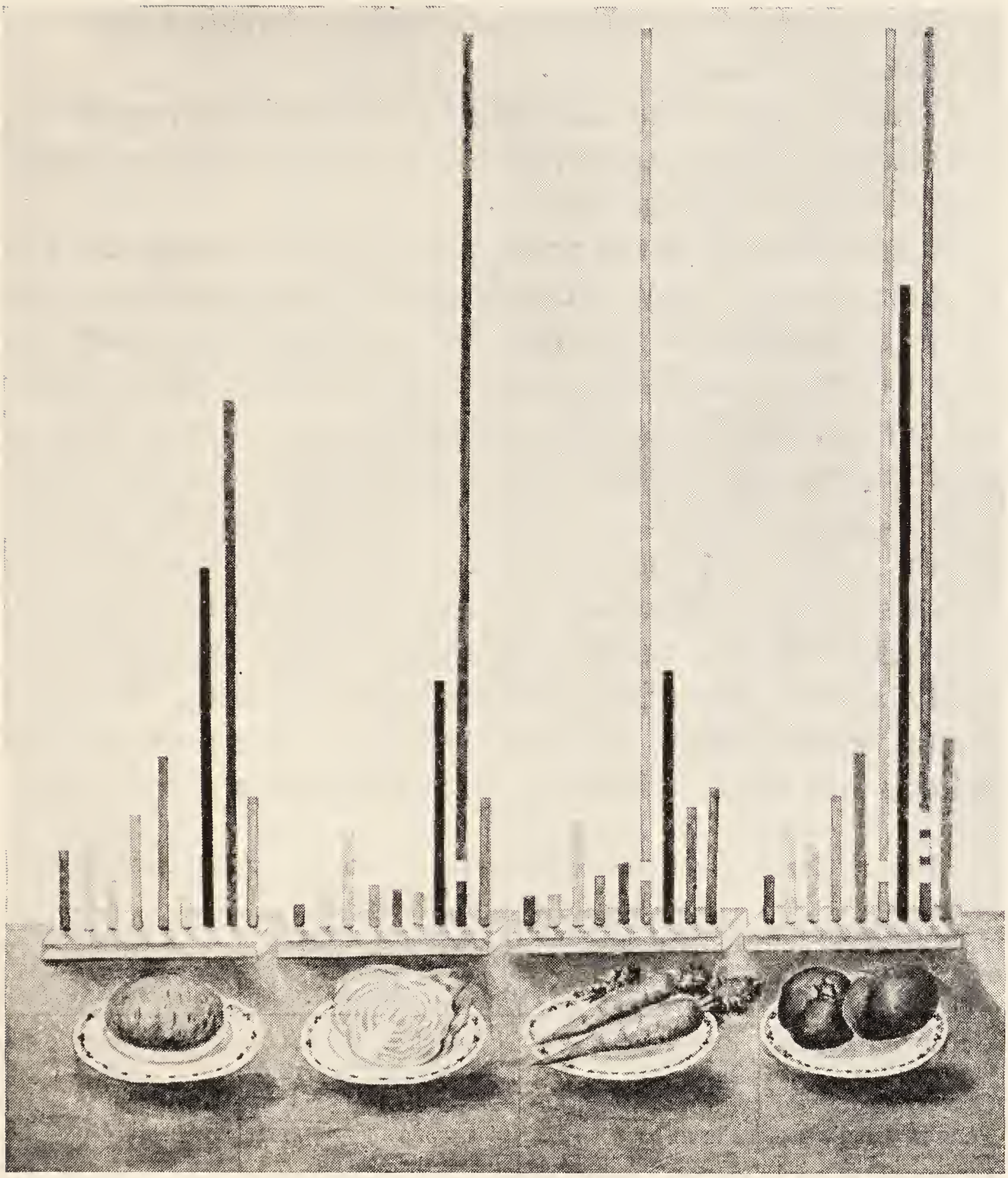

FIG. 105.—Shares Contributed to the Diet by Individual Portions of Potatoes, Cabbage, Carrots, and Tomatoes.

	SHARES IN ORDER ON BLOCKS								
	CAL.	PRO.	CA	P	FE	VIT. A	VIT. B	VIT. C	VIT. G
Potato, 1 medium (5.3 oz.) A. P.	1.0	1.1	0.6	1.5	2.2	0.3	4.8	6.6	1.5
Cabbage (2.2 oz.) E. P.	0.2	0.4	1.2	0.5	0.5	0.4	3.2	17.5	1.6
Carrots, 2 small (2.3 oz.) A. P.	0.3	0.3	1.3	0.6	0.8	20.6	3.3	1.5	1.7
Tomatoes, 2 small (8.6 oz.) A. P.	0.5	1.2	1.0	1.6	2.2	19.1	8.5	42.5	2.4

foods, and not trust entirely to arbitrary divisions based on botanical function.

Contributions to the diet made by four common vegetables, potatoes, cabbage, carrots, and tomatoes, are shown graphically in shares in Fig. 105.

As sources of iron the green vegetables are extremely important foods. They not only yield the needed iron, but provide favorable conditions for its absorption from the digestive tract and for its use in building hemoglobin. Fruits are on the whole less dependable sources of iron than of calcium, not all of them carrying enough to balance their own calories, and few carrying any considerable surplus. Fresh fruits with more than two shares of iron per 100 calories are huckleberries, blackberries, raspberries, oranges, and strawberries. Strictly speaking, the tomato, which is really a fruit, should also be included. Among the dried fruits, prunes, dates, and figs have two iron shares per 100 calories but apricots have as much as 5 or 6 shares.

Iron in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruits Shares		Root Vegetables Shares		Leaf and Stem Vegetables Shares		Dried Legumes Shares	
Dates, dried	2.1	Beets	3.7	Spinach	21.3	Beans, navy	5.8
Oranges	2.1	Turnips	3.0	Turnip greens	18.9	Beans, Lima	5.6
Grapes	1.9	Carrots	2.7	Dandelion greens	11.7	Lentils	4.9
Prunes, dried	1.9	Parsnips	2.4	Mustard greens	9.8	Beans, kidney	4.6
Figs, dried	1.8	Potatoes	2.2	Asparagus	7.6		
Raisins	1.7	Onions	2.0	Celery	6.1		
Bananas	1.3			Lettuce	5.9		
Pineapple	1.3			String beans	5.6		
Grapefruit	1.2			Brussels sprouts	4.2		
Pears	1.2			Cabbage	2.7		
Apples	1.1						

Vitamins

One of the most weighty reasons for including vegetables and fruits in the diet is to insure a liberal supply of each of the necessary vitamins. Knowledge of the vitamin content of raw foods of this class and of the changes brought about

by storing, cooking, canning, drying, etc., is therefore necessary to intelligent administration of any dietary. A table is available in the Appendix giving the relative yield of most common foods, and the discussion of sources of the vitamins in Chapters X–XVI may also be referred to.

The richest plant sources of vitamin A are thin green leaves. Of these, escarole has the highest content of any common vegetable which has been investigated, being weight for weight, when fresh, more than five times as rich as butter and per calorie share nearly twice that of spinach. Bleached leaves, such as the inner leaves of cabbage and head lettuce, have much less than similar leaves when green. Seeds are relatively poor in vitamin A, but young green peas are an exception, being weight for weight about as rich as green string beans. Roots and tubers generally contain little vitamin A, but carrots and sweet potatoes must be specially noted because they are nearly as rich as butter. Fruits resemble roots and tubers, but special mention must be made of tomatoes, which weight for weight are nearly as rich as green string beans.

Vitamin A in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruits	Shares	Root Vegetables	Shares	Leaf and Stem Vegetables	Shares	Dried Legumes	Shares
Peaches, yellow	39.2	Carrots	68.5	Escarole	1014.0	Peas, whole	3.5
Tomatoes	38.1	Potatoes, sweet, yellow	20.8	Chard	688.0	Beans, navy	0.2
Prunes, dried	6.7	Rutabagas	0.5	Spinach	618.6	Beans, kidney	0.2
Bananas	2.4	Beets	0.4	Kale	507.8		
Oranges	1.3	Potatoes, white	0.3	Dandelion greens	477.5		
Apples	1.2			Broccoli	94.2		
Pineapple	1.0			Asparagus	26.7		
Raisins	0.3			String beans	24.1		
Grapes	0.3			Lettuce	7.2		
Dates, dried	0.3			Cabbage	1.9		
Pears	0.2			Cauliflower	1.6		
Figs, dried	0.2			Celery	0.7		

Vitamin B is present in a great many fruits and vegetables, but the percentage appears to be quite low in most cases. Few vegetables are weight for weight as rich as whole grain

cereals. Peas and beans both fresh and dried are about as rich as whole wheat, but ordinary vegetables of all sorts are not more than about half as rich. Spinach is about one fourth as rich, and carrots only about one tenth. In plants vitamin B seems to be concentrated in the seeds and not in the leaves, quite the reverse of what is true for vitamins A and C.

Vitamin B in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruits	Shares	Root Vegetables	Shares	Leaf and Stem Vegetables	Shares	Dried Legumes	Shares
Tomatoes	17.0	Parsnips	11.6	Spinach	32.3	Peas, whole	17.0
Plums	14.6	Carrots	11.1	Lettuce	21.8	Beans, soy	14.5
Oranges	14.5	Turnips	8.6	Cauliflower	17.0	Beans, Lima	9.3
Pineapple	8.7	Rutabagas	8.3	Cabbage	15.9	Beans, kidney	7.3
Pears	5.5	Potatoes, sweet	5.7	Broccoli	10.8	Lentils	1.7
Grapefruit	4.3	Potatoes, white	4.8	Kale	9.8		
Apples	4.0	Beets	2.2	String beans	8.0		
Bananas	2.9	Onions	2.1				
Grapes	2.6						
Prunes, dried	2.5						
Raisins	1.7						
Dates, dried	1.2						
Figs, dried	1.1						

Vitamin C is obtained almost exclusively from vegetables and fruits, and is so irregularly distributed and so easily destroyed that one must know definitely whether the vitamin occurs in the food material in question and also in each instance the effect of storing, canning, cooking, or drying. Cabbage is an excellent antiscorbutic when raw, but loses its value rapidly in the process of cooking; tomatoes on the other hand lose but little in the short time required for cooking, and canned tomatoes may be considered a staple antiscorbutic.

The citrus fruits, especially oranges, lemons, and grapefruit, not only have a relatively high content of vitamin C in the fresh state, but retain their antiscorbutic property when properly dried. A concentrated preparation of lemon juice has been prepared in tablet form and found to retain

its antiscorbutic property over a year when stored at room temperature. Lime juice is only about one fourth as efficient as lemon juice and preserved lime juice is not dependable. Tomatoes, which are really a fruit, and tomato juice have about one half as much vitamin C as orange and lemon juice. Commercial tomato juice has about two thirds the value of orange juice. Grapes have little vitamin C and grape juice practically none. Raw bananas and apples have about the same value as an equal weight of cooked potato. Although these fruits are of distinctly lower value than the citrus fruits, they may be consumed in sufficient quantities to make them significant, as has already been pointed out in Chapter XII.

Green vegetables eaten raw vary greatly, escarole and lettuce being weight for weight like apples or celery, and broccoli like bananas; but raw green peppers are superior to oranges. Raw spinach is nearly as rich, weight for weight, as orange juice, and although there is considerable loss even with quick cooking, the larger quantity which can be consumed offsets in considerable degree such destruction of the vitamin as is brought about by the heating. In commercial canning, spinach has been shown to lose less vitamin C than in home cooking. In general vegetables should be cooked as quickly as possible to conserve vitamin C, time being a factor as well as temperature. The contributions to the diet made by four common green vegetables, lettuce, spinach, string beans, and peas, are shown in shares in Fig. 106.

Certain root vegetables rank high as sources of vitamin C if eaten raw, especially rutabagas, carrots, and onions. Carrots have the advantage of being palatable raw, and the juice of the uncooked yellow turnip has been satisfactorily used as an antiscorbutic for children when no more convenient source was available.

Mature seeds have little or no vitamin C but sprouted seeds are an important source in some parts of the world, such as China. Immature green peas are fairly rich in C,

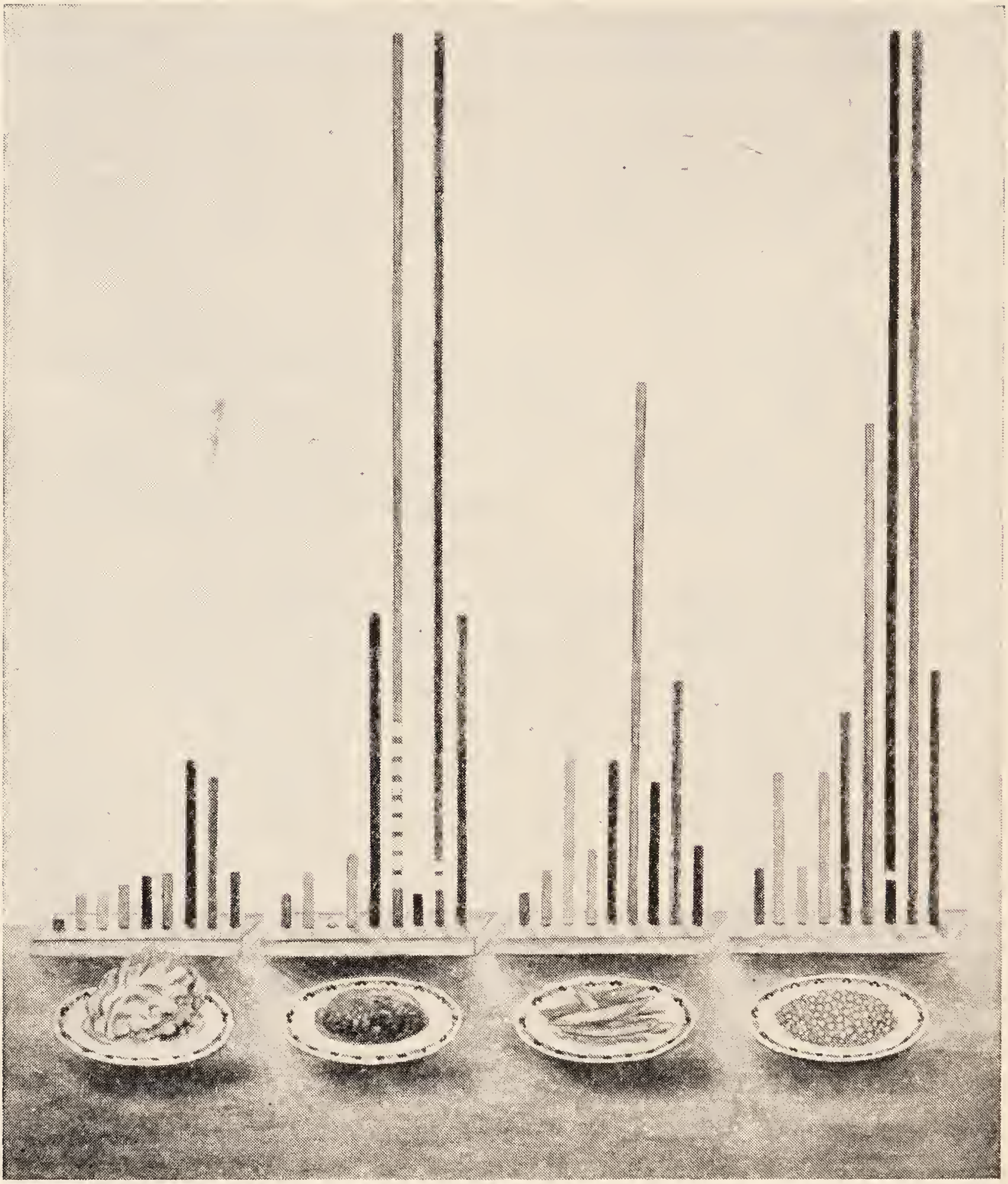

FIG. 106.—Shares Contributed to the Diet by Individual Portions of Lettuce, Spinach, String Beans, and Peas.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Lettuce, $\frac{1}{4}$ large head (2.0 oz.)	0.1	0.3	0.4	0.5	0.6	0.7	2.2	2.0	0.7
Spinach, $\frac{1}{2}$ cup, steamed (2.9 oz.)	0.2	0.7	*	0.9	4.2	123.7	0.6	27.8	4.1
String beans, steamed (2.7 oz.)	0.3	0.7	1.7	0.9	1.7	7.0	1.8	3.3	0.9
Peas, $\frac{2}{3}$ cup, steamed	0.7	2.0	0.7	2.0	2.8	7.0	15.8	12.6	3.5

* Not available.

and when canned retain a considerable part of their original supply.

Vitamin C in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruit	Shares	Root Vegetable	Shares	Other Fresh Vegetables	Shares
Tomatoes	85.0	Turnips	57.0	Peppers, green	345.0
Grapefruit	69.0	Rutabagas	49.0	Cauliflower	161.0
Oranges	59.0	Onions	15.5	Spinach, cooked	92.5
Pineapple	22.0	Carrots	7.0	Cabbage	87.5
Plums	9.0	Beets, cooked	7.0	Brussels sprouts	47.5
Peaches	9.0	Potatoes, white, cooked	6.5	Escarole	26.5
Bananas	8.5	Potatoes, sweet	5.5	Celery	25.0
Apples	8.0			Broccoli	24.0
Pears	5.5			Asparagus, cooked	23.0
Prunes, dried	2.5			Lettuce, iceberg	20.0
Grapes	2.0			String beans, cooked	11.0
				Dandelion greens	9.5

Vitamin G is formed in the growth of the green plant. Seeds are relatively poor in this vitamin, and roots and tubers are no richer than seeds. Spinach and escarole are per calorie share about twelve times as rich as potatoes and about three times as rich as cauliflower or cabbage. Fresh peas and carrots are only one fourth as rich as spinach. Fruits resemble the roots and tubers; even the tomato, so rich in vitamins A and C, is not correspondingly rich in vitamin G.

Vitamin G in Different Types of Vegetables and Fruits Expressed as Shares per 100 Calories

Fruit	Shares	Root Vegetables	Shares	Leaf and Stem Vegetables	Shares	Dried Legumes	Shares
Tomatoes	4.9	Turnips	5.7	Beet greens	37.8	Beans, soy	13.1
Prunes, dried	4.4	Carrots	5.6	Escarole	23.0	Peas, whole	5.0
Grapefruit	4.3	Beets	5.5	Spinach	20.9	Beans, Lima	4.5
Pears	4.0	Rutabagas	4.9	Kale	19.6	Lentils	1.1
Apricots, fresh	3.7	Potatoes, white	1.5	Broccoli	18.9		
Oranges	3.1	Potatoes, sweet	1.4	Cauliflower	9.9		
Pineapple	2.2	Onions	1.4	Cabbage	8.0		
Apples	1.6			Lettuce	7.2		
Bananas	1.5			String beans	3.0		
Raisins	0.7						
Figs, dried	0.7						
Blueberries	0.4						

Summary

Vegetables and fruits vary greatly in energy value. Only the dried seeds of legumes and sweet dried fruits approximate cereals in calories per pound. The relative value of the others depends chiefly on the amount of starch or sugar present. Green leaves and stems have little fuel value.

With the exception of dried legumes, few fruits or vegetables are used in quantities which make their protein content very significant for the diet as a whole. The quality of the legume proteins tends to be rather poor, but soy beans and peas have proteins adequate for growth. Most vegetables carry at least enough protein to balance their own calories from the quantitative standpoint, but fruits do not.

As sources of mineral elements of the many kinds required by the body, vegetables and fruits deserve a higher place in the diet than has generally been accorded them in the past. Green vegetables are especially valuable as sources of iron and for providing copper, essential for its absorption and use in building hemoglobin. The ash of fruits is usually of such character as to help greatly in maintaining the normal neutrality of the blood.

As sources of vitamins, vegetables and fruits are of the greatest value. Thin green leaves are as a rule rich in vitamins A, B, and G. Fruits and vegetables which are eaten raw usually contribute significant amounts of vitamin C but the citrus fruits and tomato juice, which can be eaten regularly in considerable quantities, are one of the best guarantees of adequate daily amounts of this vitamin. They lose little in cooking or canning; many vegetables and other fruits lose much if not all of their vitamin C content. Vitamin B is quite irregularly distributed in fruits and vegetables, and it is well to supplement these with milk and whole grain cereals (or at least the germ) to insure a liberal intake. Vitamin G is also variable, and while green leaves are fairly good sources, they should be supplemented by richer sources, as milk, eggs, liver, kidney, or other meat.

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CHAPTER XX

EGGS, CHEESE, NUTS, MEAT, AND OTHER FLESH FOODS

Eggs

Among the food groups so far considered none but milk can be designated an outstanding source of protein. Cereals and many vegetables have protein enough to "balance" their own calories, but with the exception of the legumes none will have surpluses to make up for the shortcomings of fuel foods totally devoid of protein, such as fats and sugars. A quart of milk in the diet of a child whose body weight is under 60 pounds (a weight not attained much before the seventh year) will amply safeguard the diet as to total protein, but subsequently there will be need of other foods to reinforce the diet in this direction. In making a selection from available sources of protein it is wise to pay attention to other growth promoting substances which may be secured incidental to the protein. From this point of view, the egg would be the first choice, and especially the yolk, which is rich in all substances necessary for growth except calcium and vitamin C. In fact, a small amount of egg yolk may profitably be included in the diet of breast fed babies as early as the fifth or sixth month, and in that of artificially fed babies earlier in the first year, entirely for the sake of other nutritive factors beside protein. By the time the child is two or three years old, the whole egg may become a regular part of the daily diet.

The chief protein of the egg yolk (ovovitellin) resembles casein of milk in its amino acid content and so does that of the white (ovalbumin). Both are therefore complete proteins independently capable of supporting growth and valuable in bringing to full efficiency proteins of lower value such as the cereal proteins. Next to milk, eggs are the most

important protein-bearing food in the diet of the growing child.

SHARES OF IRON IN ONE EGG YOLK COMPARED WITH THOSE IN AMOUNTS OF OTHER FOODS CONSUMED WITH SIMILAR EASE

FOOD MATERIALS	AMOUNT	SHARES OF IRON
Egg yolk	1 yolk	2.6
Spinach, steamed	$\frac{1}{3}$ cup	2.8
Peas, fresh	$\frac{1}{2}$ cup	2.7
Wheat, shredded	1 biscuit	2.5
Oats, rolled, dry	$\frac{1}{4}$ cup	2.4
Farina, dark, dry	$\frac{1}{8}$ cup	2.1
Beef, lean	1 ounce	1.7
Potato	1 small	1.5
Beans, string	$\frac{1}{2}$ cup	1.2
Carrot, diced	$\frac{1}{2}$ cup	0.8
Lettuce	$\frac{1}{8}$ large head	0.4

The ash constituents of the egg are mainly found in the yolk, which carries more calcium and phosphorus and nearly five times as much iron as needed to balance its own calories, as shown in Fig. 108. The iron in egg yolk compares very favorably in quantity with that in other foods which may be considered significant sources of iron, as the preceding table demonstrates.

SHARES OF PROTEIN, CALCIUM, PHOSPHORUS, AND IRON, AND VITAMINS A, B, C, AND G IN 100 CALORIES OF MILK, OF EGG, AND OF MILK AND EGG COMBINED IN PROPORTIONS OF ONE EGG TO A QUART OF MILK

	MILK SHARES	EGG SHARES	MILK AND EGG (IN PROPORTIONS OF ONE EGG TO ONE QUART OF MILK) SHARES
Calories	1.0	1.0	1.0
Protein	1.9	3.6	2.0
Calcium	7.4	1.8	6.9
Phosphorus	3.1	3.4	3.1
Iron	0.7	3.9	1.0
Vitamin A	3.0	13.4	4.0
Vitamin B	1.6	3.9	1.8
Vitamin C	1.6	—	1.5
Vitamin G	2.3	4.9	2.5

The white of the egg is unique in being the only known source of vitamin G unassociated with vitamin B. The yolk is rich in vitamins A, B, D, and G, but has no vitamin C. One whole egg has about the same amount of vitamin A as

3 cups of milk, of vitamin B as $1\frac{1}{2}$ cups, and of vitamin G as $1\frac{1}{3}$ cups. The amount of vitamin D in egg yolk is small compared to that in cod liver oil, 12 egg yolks having about the same amount as 1 teaspoon of cod liver oil. Eggs cannot be regarded as a substitute for milk, but may be advantageously used in addition to it. They admirably reinforce milk as to iron, as will be seen from the preceding table in which one egg is combined with a quart of milk.

Cheese

Of approximately two thousand tons of cheese manufactured annually in the United States the major portion is of the "American" variety. A pound of such cheese contains the casein and fat of a gallon of milk, together with traces of whey retained by the curd. It has about one fourth of its calories in the form of protein and the other three fourths in the form of fat. The milk sugar is mostly withdrawn in the whey, or changed to lactic acid in the ripening process. The calcium, phosphorus, and iron of the milk are retained in the cheese and also a large part of the vitamin A. The contributions to the diet made by a $1\frac{1}{8}$ inch cube of American cheese are graphically portrayed in Fig. 108, and the striking resemblance between the contributions of this amount of cheese and those made by a glass of milk will be readily perceived by reference to Fig. 101.

Such a concentration of the most important nutritive elements of milk in a food of excellent keeping qualities entitles cheese to a place in the diet which is not always fully appreciated. Its strong flavor precludes its use in many of the ways in which milk is practical and makes it more akin to meat in regard to its place on the menu, but as a substitute for meat it gives a much better return in nutritive value for the money expended, and is particularly valuable as a source of calcium in the diet of adults who have not acquired the habit of using milk freely.

Because of its flavor cheese is often regarded as a condiment and served with other foods merely to add zest to a

meal. It should be remembered, however, that cheese is a concentrated food and is properly used in the diet much as meat would be. Because of its texture and its high proportion of fat calories to total calories it is digested best when used with bread or other cereal foods, and when very thoroughly masticated or cooked in such a way as to be soft and not leathery. Too large a quantity will sometimes prove irritating to the stomach because of small amounts of certain substances developed in the ripening process, but knowledge of its concentrated nature should lead to due restraint. Half a pound of cheese will provide sufficient protein of the best quality for an average man for a day, and fully one third of his total calories. The simple addition of a pound of whole wheat bread and a couple of pounds of fruit will result in a diet adequate for an adult in every respect and at a most moderate outlay of money and effort.

Nuts

Nuts are often regarded as a mere adjunct to the dietary to be nibbled between courses at dinner, to add interest to afternoon tea, or to be eaten between meals for pure amusement. Thus used they may prove disturbing to digestion or furnish calories in excess of body needs, for they contain chiefly protein and fat and digest rather slowly and their fuel value is very high. About half an ounce of almost any one of our common nuts is sufficient to yield 100 calories. This means the small matter of two Brazil nuts, eight to ten filberts, half a dozen medium sized pecans, or a dozen peanuts. Chestnuts are the only notable exception to this concentration of energy, about three times as much by weight being required to get 100 calories from them as from other common nuts. In their yield of protein, fat, and carbohydrate, chestnuts are almost exactly like graham crackers, as will be seen from Fig. 107; when dried they have the same number of calories per pound as the crackers. Our other common nuts yield at least twice as many calories in the form of fat as of protein and carbohydrate together, and resemble ordinary

gravity cream or the rich milk secured by removing a certain number of ounces from the top of a quart bottle which has been standing long enough for the cream to rise. The kind of cream or milk which some of our most widely used nuts closely resemble is also shown in Fig. 107.

The proteins of nuts of various kinds, including almonds, coconuts, peanuts, and pecans, have been found to be ade-

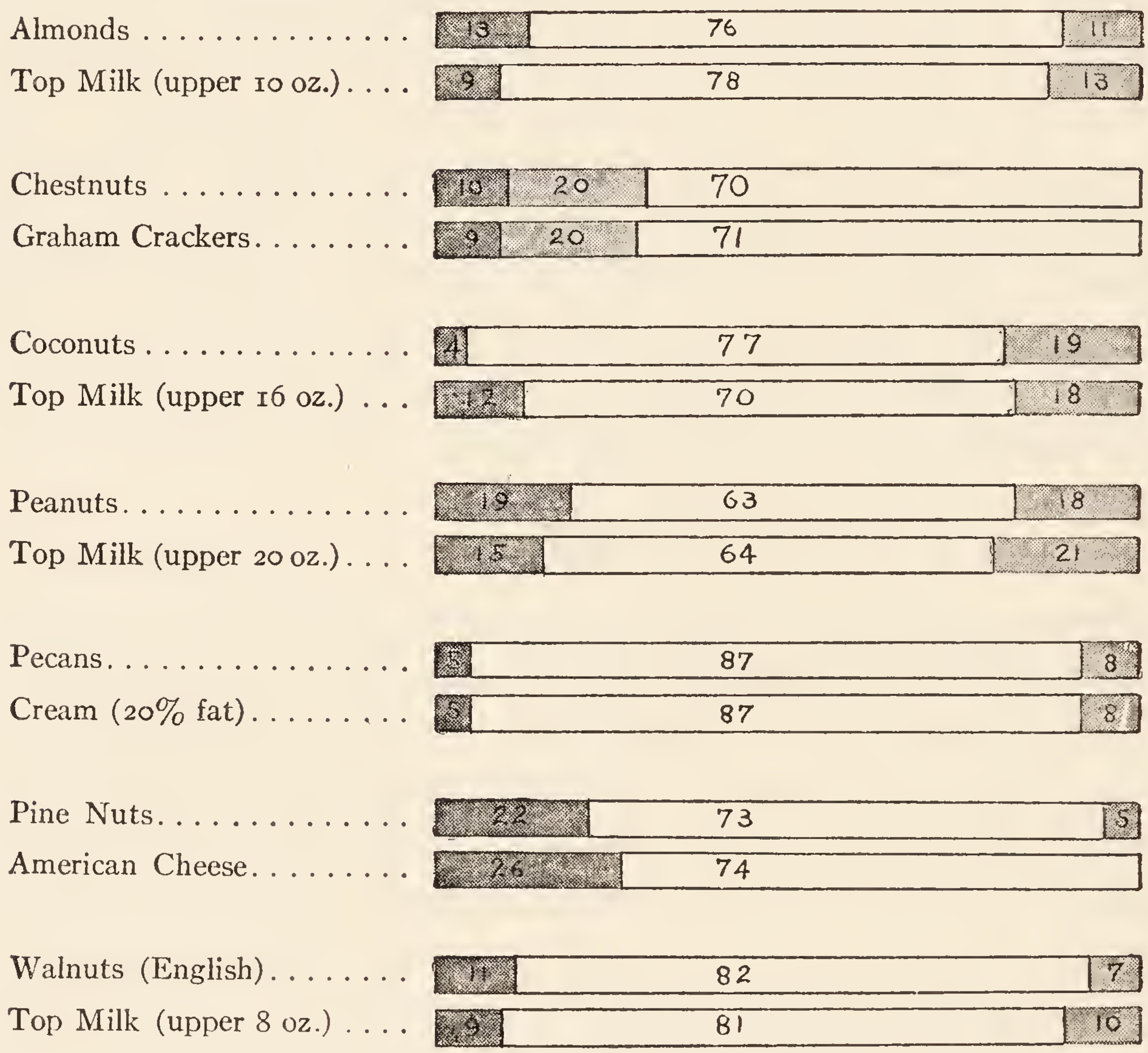

Fig. 107.—This chart shows the number of calories from protein, fat, and carbohydrate respectively in a 100 calorie portion of some common nuts and the food which they most closely resemble in distribution of calories.

quate for growth, and chemical analyses of individual proteins from some of these have shown an amino acid assortment rather similar to that of meat. Peanut flour, made from the press cake left after the extraction of the peanut oil, has been found an excellent supplement to the proteins of wheat, a bread made with 75 per cent wheat flour and 25 per cent peanut flour giving a mixture in which the protein was adequate for the normal growth of white rats.

In nuts as ordinarily eaten, the proportion of protein to total calories is generally too low to expect them to contribute very significant quantities of protein to the diet. Exceptions are almonds, which have one and three tenths shares of protein for every calorie share, peanuts with nearly two protein shares, and pine nuts (pignolias) with two and one quarter shares per calorie share. These foods are therefore of some importance as sources of protein. The combination of two energy shares of bread (200 calories) with one of peanuts (100 calories) results in a mixture with such proportions of protein, fat, and carbohydrate as characterize a good mixed diet, and with one and one half protein shares for each energy share, guaranteeing adequacy both as to quantity and quality of protein at a very moderate cost.

As sources of minerals nuts as a class are not of much importance because here, again, the amount of mineral element per energy share is usually less than one. Among nuts for which we have ash analyses, peanuts and almonds are outstanding in regard to phosphorus, having one and two-thirds shares per calorie share, and almonds and filberts are distinguished by furnishing slightly more than their own quota of iron.

Nuts are poor in vitamin A and the oil pressed from them is practically devoid of it. They resemble the cereal grains as sources of vitamins B and C, having a considerable supply of vitamin B and practically none of vitamin C. With the exception of peanuts, which are a good source, they have not been investigated as to vitamin G.

Compared with cream and top milk, which they so closely resemble in their energy yield, nuts furnish protein similar in quantity and probably not quite so good in quality; they are distinctly inferior as sources of calcium, not even excepting almonds and filberts which are far above the nut average. A number of them resemble thin cream in phosphorus content, and all of them carry more iron than cream, but, excepting almonds and filberts again, not enough to balance their own calories. As sources of vitamins they are far inferior to cream as regards vitamin A.

A COMPARISON OF SOME COMMON NUTS AND GRAVITY CREAM
EXPRESSED IN SHARES

	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Cream (18% fat)	1.0	0.5	2.2	1.0	0.2	3.8	+	−	+
Almonds	1.0	1.3	1.7	1.6	1.2	+	1.3	−	+
Chestnuts	1.0	1.0	0.6	0.9	0.6		4.5	−	+
Coconuts	1.0	0.4	0.2	0.3	0.6	+	+	−	+
Filberts	1.0	0.9	1.8	1.1	1.1	+	3.1	−	+
Peanuts	1.0	1.9	0.5	1.7	0.7	+	4.0	−	1.8
Pecans	1.0	0.5	0.5	1.0	0.7	0.3	1.4	−	+
Walnuts, English	1.0	1.0	0.6	1.2	0.6	+	4.3	−	+

Because of their dense nature, nuts are not easily penetrated by the digestive juices. To be readily digested they need therefore to be very thoroughly masticated or else finely ground. Peanut butter is an excellent example of a nut prepared in a way to increase ease of digestion. Nuts should also be combined with foods low in fat if they are to be consumed in any considerable quantity; otherwise their high fat content makes the total fat of the diet too great for speedy gastric digestion. When these considerations are given due weight, nuts are an excellent kind of food, and may well be used more freely than is generally the practice. A meal which requires no cooking and is adequate in all respects

LUNCHEON WITH PEANUTS AND FIGS IN SHARES

	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, whole wheat	3.0	4.5	3.3	4.5	3.6	−	16.2	−	2.1
Butter	1.5	−	−	−	−	7.8	−	−	−
Peanuts	2.0	3.8	1.0	3.4	1.4	+	8.0	−	3.6
Figs	2.0	1.0	4.4	1.6	3.6	0.4	2.2	1.2	2.1
Total	8.5	9.3	8.7	9.5	8.6	8.2	26.4	1.2	7.8
Average	1.0	1.1	1.0	1.1	1.0	1.0	3.1	0.1	0.9

except vitamins C and G can be secured from bread and butter, dried fruit, and nuts. The inclusion of a little orange juice or lemon juice would add the lacking vitamin C. Such a meal is most economical, both as regards initial outlay and the labor involved in preparation, serving, and dishwashing. Many busy people could well adopt such a meal once a day. A luncheon of this character, with sufficient food for a sedentary adult, is given in detail above. It will be noted that

every energy share in the mixture carries its own quota of protein, calcium, phosphorus, and iron. The butter furnishes vitamin A, and the whole wheat bread considerable vitamin B.

Meat and Other Flesh Foods

At the present time Americans spend more money for meat than for any other one type of food although the amount spent for fruits, vegetables, and milk is fortunately increasing and that for meat decreasing. According to Sherman's analysis of 224 typical family dietaries, an average of one third of the food money is invested in meat, with a return of less than one fifth of the total calories. The meat consumption of Americans has generally been about 170 pounds per capita per year, or nearly half a pound apiece every day for each man, woman, child, and infant in arms. As mere infants and some folk older eat none and some others very little, it follows that many must have a great deal. Is this expenditure of so much money for meat wise? Does it help to guarantee to the American people well balanced diets? The only way to answer these questions is by careful study of the nutritive value of the principal flesh foods. In connection with the prevailing market meats, beef, veal, mutton, lamb, and pork, we may also discuss poultry, game, fish, and shellfish, since nutritionally they have the same characteristics. For the most part, Americans eat muscle tissue to the exclusion of other parts of the animal. Oysters and sardines are the only animal foods of any considerable importance in which the whole body is consumed. This is in marked contrast to the habit of carnivorous animals and of people living chiefly on animal food, none of whom let any part go to waste.

All kinds of flesh foods contain protein and usually fat; the fat varies greatly in amount with the species of animal and also in case of the larger creatures with the cut. The amount of fat chiefly determines the proportions of other substances, the fat free flesh being quite uniform in composition. The distribution of calories between fat and protein

in flesh foods of various kinds is shown in the following table. Many have more fat than full cream cheese.

Distribution of Calories in 100 Calorie Portions of Lean Meats

	Protein Calories	Fat Calories
Cod steak	94	6
Chicken broilers	80	20
Tuna fish	70	30
Veal, leg, lean	70	30
Chicken heart	62	38
Halibut steak	61	39
Herring	55	45
Beef, lean	54	46
Salmon, fresh	43	57
Mutton, leg, lean	41	59
Pork, loin chop, lean	32	68
Ham, lean	30	70

The amount of any mineral element in meat or fish is proportional to the amount of protein present rather than to the total calories. Lean meats are therefore richer in mineral elements than fat meats, and the higher the percentage of fat, the fewer shares of any mineral element per hundred calories.

All meats resemble the cereal grains in being deficient in calcium, and rich in phosphorus. Codfish appears exceptionally rich in calcium, because it contains practically no fat.

Calcium and Phosphorus in Cereal Grains, Lean Meats, and Fish Expressed in Shares per 100 Calories

Cereal Grains Shares			Lean Meats Shares			Fish Shares		
	Ca	P		Ca	P		Ca	P
Buckwheat flour	0.1	1.2	Beef, lean	0.4	3.0	Cod, steak	0.6	5.4
Cornmeal	0.2	1.0	Chicken broilers	0.5	4.9	Halibut, steak	0.3	3.8
Oatmeal	0.7	2.2	Liver, beef	0.4	6.5	Herring	0.7	3.6
Rye flour	0.2	1.9	Veal, lean leg	0.5	4.1	Salmon, fresh	0.2	2.7
Wheat, whole	0.4	2.0						

The proteins of meats of all kinds are much alike in furnishing a good assortment of essential amino acids, and hence capable of supporting growth, though in no way superior to milk and egg proteins. Like the latter they supplement the proteins of the cereal grains, but are not superior to either for

this purpose. Quantitatively, lean meat is conspicuous for its high yield of protein, but any increase in fatness quickly changes the proportion of protein to total calories, as the following table indicates:

Protein in Edible Portions of Lean Meat
Expressed in Shares per 100 Calories

Cod steak	9.5
Chicken broilers	8.0
Tuna fish	7.0
Veal, lean leg	7.0
Halibut steak	6.1
Herring	5.5
Beef, lean round	5.5
Salmon, fresh	4.3
Mutton, leg	4.2
Lamb, leg	3.4
Pork, loin chop	3.2
Ham, lean	3.0

According to Sherman, the iron in meat of a given sort is closely proportional to the protein content, and we may expect that iron will be high or low in a given piece of meat according as the protein is low or high. Internal organs, such as the heart, brain, liver, and kidney are much richer in iron than muscle tissue.

While strictly lean meat resembles the egg in having a higher iron content than the cereal grains, meats as ordinarily eaten and most fish are more like the grains than they are like the egg.

As sources of vitamins, it is necessary to consider separately muscle meats and glandular organs. The former have very little vitamin A or C, but are fairly good sources of vitamin G. Most muscle meats are about the equivalent, weight for weight, of eggs as sources of vitamin B, but lean pork is outstanding in this vitamin, having five or six times as much as whole eggs. Liver and kidney are about equal as sources of vitamin G, and are weight for weight at least six times as rich as whole egg. Kidney is a poor source of vitamin A while liver has at least five times as much as whole egg. The vitamin C which they contain is mostly destroyed in cooking.

Iron in Meats and Fish Compared with the Cereal Grains Expressed in Shares per 100 Calories

Cereal Grains	Shares	Muscle Meat	Shares
Barley, entire	2.7	Beef, lean round	3.8
Oatmeal	2.4	Mutton, lean leg	1.7
Rice, brown	2.2	Lamb, lean leg	1.4
Rye, entire	2.2	Pork, loin chop	1.2
Wheat, whole	2.0	Ham, lean	1.1

Fish	Shares	Internal Organs	Shares
Tuna, fresh	1.9	Liver, beef	12.7
Halibut steak	1.6	Heart, beef	8.7
Herring, fresh	1.5	Kidney, veal	6.6
Salmon, fresh	0.9	Eggs	3.9
Cod steak	0.9		

From the foregoing it is evident that, aside from total calories, the most significant contributions of ordinary meat to the dietary are protein, iron, and vitamin G, and in case of pork vitamin B. But it should be borne in mind that the amount of protein yielded by a lamb chop can be obtained from an egg equally well, or one and one fourth ounces of cheese, or a glass of milk, at much less cost and that vitamin G will be furnished at the same time. The second most important contribution of meat is iron, but again, it has no monopoly of this important element; a quarter of a cup of cooked spinach or three fourths of a cup of string beans or an egg yolk or two slices of whole wheat bread furnish quite as much as a lamb chop, and at less cost.

The chief advantages of meat seem to be its palatability, ease of preparation for the table, and ease of digestion. For these reasons, some meat in the dietary is very acceptable. If the meat is used to increase the consumption of milk, vegetables, and fruits, and not to displace them, it may be a desirable though rather expensive addition to the diet.

The contributions to the diet made by an egg white and an egg yolk are compared in Fig. 108, and also those made by individual portions of American cheese and lean beef.

Liver and kidney are very different in their nutritive values from the muscle tissue so generally preferred by

Americans, being rich in the vitamins in which muscle is so conspicuously deficient, and surpassing it in the one vitamin for which it is worthy of mention—vitamin G.

Liver is also abundantly supplied with copper, essential

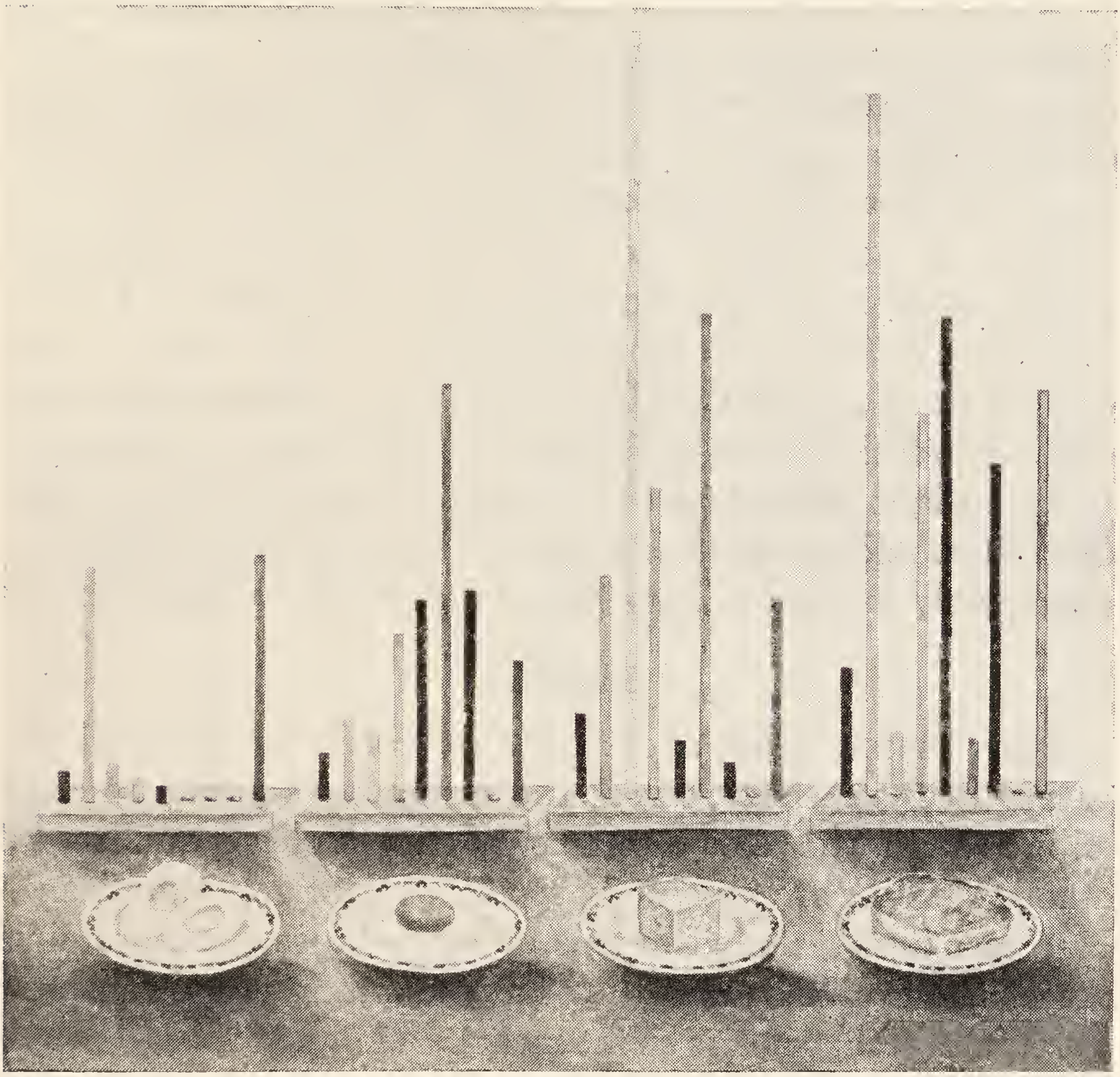

FIG. 108.—Shares Contributed to the Diet by Individual Portions of Egg White, Egg Yolk, American Cheese, and Lean Beef.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Egg white	0.3	2.9	0.3	0.2	0.1	—	—	—	2.9
Egg yolk	0.5	0.9	0.8	1.9	2.3	5.0	2.5	—	1.6
American cheese ($1\frac{1}{8}$ in. cube)	1.0	2.6	9.2	3.6	0.6	5.8	0.4	—	2.3
Lean beef (3.0 oz.)	1.5	8.2	0.5	4.5	5.7	0.6	4.0	—	4.8

to iron utilization, and in studies in which animals have been made anemic by bleeding, liver has proven especially effective in iron regeneration, supplying other factors besides iron

and copper needed in the reconstruction of normal red blood corpuscles.

The use of small amounts of liver in the diet of young children may be regarded as a distinct advance over the use of ordinary muscle meats. There seems to be little reason, however, to think liver superior to egg yolk for this purpose. Rose and Borgeson [1] added to the diet of nursery school children, who had been observed on a régime without any egg for $2\frac{1}{2}$ years, enough liver to furnish the same amount of iron as an egg a day, and compared them with a group, matching them in age and living conditions, who had been continued on the same type of diet plus an egg daily. Tests of the hemoglobin of the blood and of the number of red cells showed practically no difference in the former, and if anything a slight advantage of the egg over the liver in the latter. It would seem that liver and egg can be used interchangeably in the ordinary mixed diet of normal children.

Summary

Eggs, cheese, meat, and other flesh foods are grouped together because they possess the common property of contributing to the diet proteins of the highest quality in amounts which are absolutely as well as relatively significant. Nuts are also included in this group because their proteins are of good quality, and they have as much protein in proportion to total calories as fat meats.

Eggs in addition to protein are rich in vitamins A, B, and G and also in iron and phosphorus; they therefore serve like milk to reinforce the diet at several points and deserve special emphasis for their growth promoting properties. American cheese represents a concentration of most of the protein, fat, calcium, phosphorus, and iron of the milk from which it is made. It also contains a large part of the vitamin A of the milk. Used interchangeably with eggs and meat as a source

[1] Rose, M. S., and Borgeson, G. M. "Child Nutrition on a Low-Priced Diet with Special Reference to the Supplementary Value of an Egg a Day, the Effect of Adding Orange Juice and of Replacing Egg by Liver." *Child Development Monographs*, No. 17, page 70. Bureau of Publications, Teachers College, Columbia University (1935).

of protein, it adds calcium, in which meat is very deficient and eggs somewhat low. Meat in the American diet means chiefly muscle tissue, which unless very fat is high in protein, phosphorus, and iron, and fairly rich in vitamin G, but very deficient in calcium and in vitamins A and C and not significant for vitamin B.

Liver and kidney are relatively rich in vitamins A, B, and G, but like other meats need to be supplemented by milk or cheese for calcium, and by some fruit or vegetable for vitamin C.

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CHAPTER XXI

FATS, SUGARS, AND OTHER SWEETS

Fats and sugars are primarily sources of energy. As body fuel, fats and sugars are interchangeable calorie for calorie under ordinary living conditions. Sugar required in the body can be derived from starches, dextrins, or from proteins. Certain fatty acids which seem indispensable are easily obtained in the minute amounts needed. Yet the World War taught us what an important part fats and sugars can play in sustaining or destroying the morale of a people. In the United States where other food was abundant the saving of sugar to send overseas was accomplished only by a widespread and systematic educational campaign in which "sugar-saving sweets" were constantly featured. In daily life, fats and sugars are not interchangeable. The diabetic, deprived of sugar, finds small consolation in a generous allowance of fat. Sugar does not altogether make good the feeling of emptiness on a ration devoid of fat. Even though they yield calories only, both are needed to make a perfectly satisfactory diet for most human beings.

Fats

Fat is the most concentrated form of body fuel, just as petroleum oil is the most compact fuel for the furnace. It takes only one half an ounce (one tablespoonful) of fat to yield 100 calories, and a person could get a whole day's fuel from three quarters of a pound of fat if he were able to eat it. On the other hand, people of the Orient who on account of poverty live largely upon rice and in consequence have to eat a great quantity of food to secure sufficient fuel for their daily activities, develop distended abdomens. It would take nearly eight pounds of cooked rice to give the same

number of calories as three quarters of a pound of fat or oil. The latter would not fill a pint measure; the former pressed down would overflow a gallon measure. When for any reason a person is put on a milk diet for a considerable time, it is customary to add something to the milk to increase its concentration (such as more cream and more milk sugar), if any attempt is made to keep the energy intake up to what it would be on a full mixed diet. A man's energy requirement can be met by four to five quarts of milk per day if he is not doing extremely heavy manual labor, but it would be more satisfactory to substitute for one quart of the milk a loaf of bread, which is comparatively dry, and for another quart, three ounces (six tablespoonfuls) of butter, thus reducing the volume without any change in energy value. For growing boys and girls and for men engaged in strenuous physical exercise, fat is almost essential if they are to get enough total calories.

Furthermore, fat gives the diet "staying" qualities. Other things being equal, one feels hungry sooner after a meal with little fat than after one in which it is liberally supplied. This is because fat leaves the stomach more slowly than proteins or carbohydrates and retards the digestion of either of these when used in combination with them. A mixture of fat and protein digests more slowly than one of fat and carbohydrate. Probably part of the popularity of meat is due to the fact that it is a protein-fat mixture in which the fat contributes very definitely to the feeling of satisfaction after the meal. The feeling of dissatisfaction among the Europeans on their low fat war ration was in large measure due to this effect of fat on digestion.

Too much fat may result in undue slowness of digestion and digestive upsets. How the fat is used in cooking also has much to do with its ease of digestion. Butter spread cold upon bread will digest more easily than butter fried into potatoes or incorporated in a sweet cake. The texture produced in the potatoes will not be favorable to rapid digestion and the fat will also exert its retarding influence.

For a young child, the summation of effect is too great a risk. The sugar of cake is likewise a complicating factor. The same amount of sugar eaten pure at the proper time might be diluted and passed along to be quickly absorbed, whereas the mixture is likely to be disposed of more slowly and not always harmlessly.

Used with proper discretion, all of our common food fats, both animal and vegetable, digest easily and completely. As sources of energy the different food fats are practically interchangeable and which we eat may be determined by preference and convenience. Some prefer olive oil, some pork fat; others revel in seal oil. The ancient Romans prized vegetable oil for food and butter for cosmetics. For a long time it was not known that there were fat soluble vitamins, but now we have to consider fats also as possible sources of these dietary essentials. As Sherman has pointed out, "A surplus of vitamin A is not simply a reserve asset to be used at some future time but also actively increases the vigor and ability of the body to resist disease." Careful consideration should be given to the bearing which this has upon the choice of fat. If a quart of whole milk is consumed daily, it will furnish as much vitamin A as about two ounces of commercial butter, and if in addition to the milk, green vegetables are consumed in liberal amounts, there need be no fear of a deficiency of vitamin A. When milk is less freely used (and a survey of 197 towns in 12 states in 1926 showed the average per capita consumption to be far below any desirable amount, averaging slightly over half a pint),[1] the habit of eating butter is certainly a safeguard of real importance. Vegetable oils, whether fluid or hardened by hydrogenation, are lacking in vitamin A and such animal fats as are used in butter substitutes have relatively little. One tablespoon of butter contributes to the diet 1 calorie share and 5.1 vitamin A shares; 1 tbsp. of cod liver oil, 1 calorie share and 47.8 vitamin A shares; 1 tbsp. of olive oil

[1] Crumbine, S. J. "A Campaign for Clean and Safe Milk." Address at American Health Congress, May 22, 1926.

only 1 calorie share as shown in Fig. 109. Butter substitutes may be as valuable as butter, however, if a vitamin A concentrate is added in their manufacture and biological tests

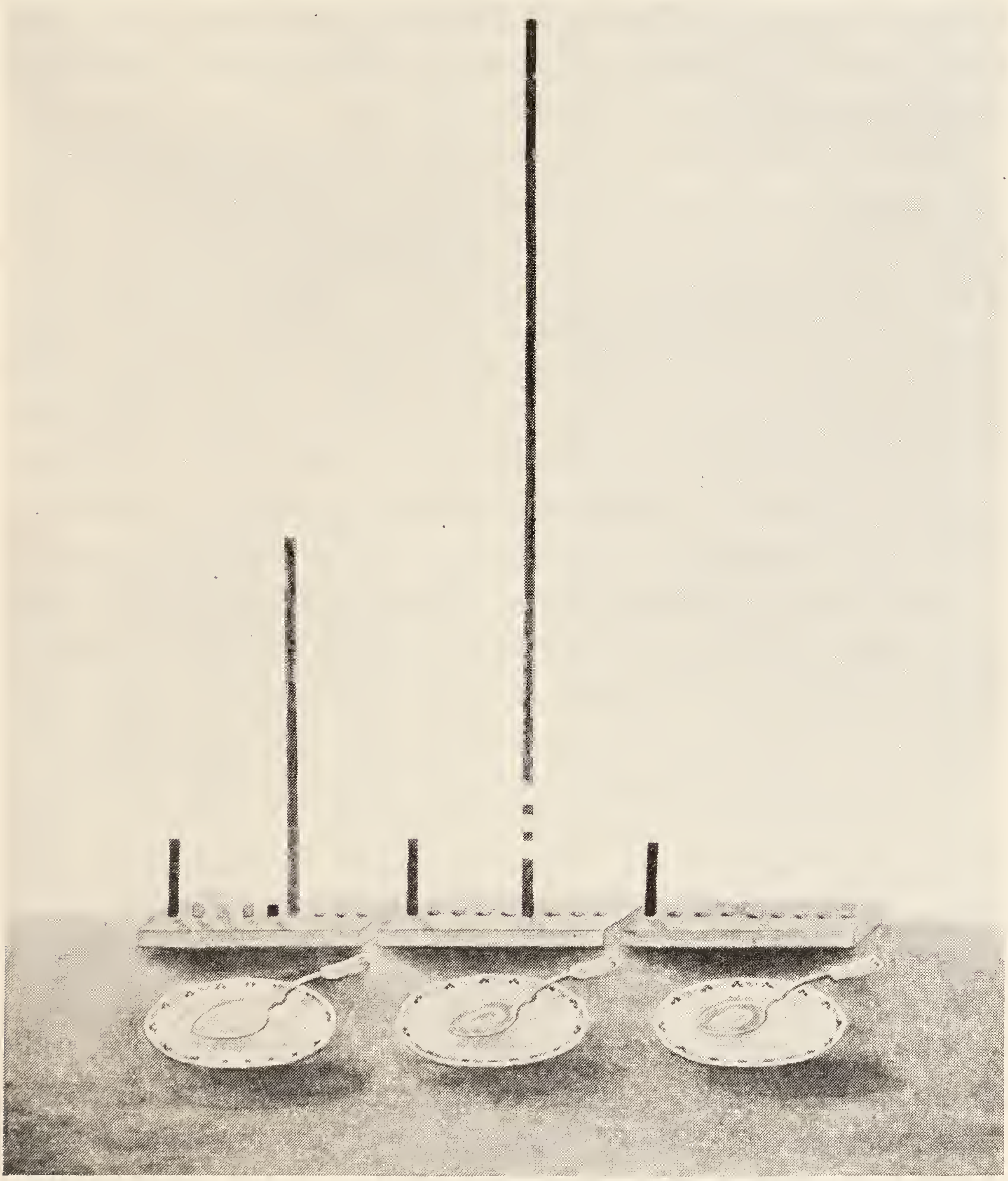

FIG. 109.—Shares Contributed to the Diet by One Tablespoon Each of Butter, Cod Liver Oil, and Olive Oil.

prove the vitamin A content of the finished product; otherwise they are butter substitutes only in the sense of furnishing equivalent calories or something which can be used in the menu in the same way as butter.

In some parts of the world cod livers, richer sources of vitamin A than butter, are a staple article of the diet. But in this country, cod liver oil is used separately from other food as its flavor does not generally commend itself to adults, though young children seem to like it. A tablespoonful of cod liver oil will furnish at least ten times as much vitamin A as the same amount of butter.

The administration of cod liver oil to young children for the sake of its antirachitic vitamin has the additional advantage of increasing the intake of vitamin A. Since, weight for weight, egg yolk is about as rich in vitamin A as butter, or calorie for calorie is twice as rich, the free use of eggs permits more choice as to the kind of fat. It is often better household economy to buy milk and a butter substitute than to spend the same amount of money for cream or butter. In butter substitutes refined vegetable oils, such as cottonseed, coconut, and peanut, and oils derived from beef or lard are so combined or treated as to produce the desired hardness and churned with milk or milk and butter to improve flavor and texture. If more milk, green vegetables, and eggs can be bought by substituting such a product for butter, the diet will probably be improved. But if there is no danger of restricting the diet too much in some other direction, the purchase of butter, rich in vitamin A, may be regarded as an investment with an assured return.

Sugars and Other Sweets

The common food sugars are cane sugar or sucrose, milk sugar or lactose, malt sugar or maltose, glucose or dextrose, and fructose or levulose. Cane sugar of commerce is derived from the sugar cane and sugar beet. Milk sugar differs chemically from cane sugar, being less sweet, less easily dissolved in water, and less easily fermented. Malt sugar is made by the partial digestion of starch. It does not appear in the ordinary market as pure malt sugar, but as a mixture of about half maltose and half dextrin. This "malt food" is not very sweet and is popular for use in the modification

of cow's milk for babies, either in conjunction with lactose or as a substitute for it. Glucose occurs widely in nature, but is obtained commercially by chemical treatment of starch. It does not appear in the food market as pure glucose but as "commercial glucose" or "corn syrup" which contains about as much dextrin as glucose. It is not very sweet, and table syrups made from it are flavored with the sweeter refiner's syrup from the manufacture of white cane sugar. Fructose occurs in many fruits, but honey is the only common food containing a high percentage. Honey contains nearly equal proportions of fructose and glucose plus a little sucrose. Its flavor comes from substances found in minute quantities in the nectar of the flowers from which it is made. It has in addition traces of mineral matter but no vitamins.

Maple syrup and maple sugar consist of the concentrated sap of the sugar maple, and contain a certain amount of mineral matter as well as flavoring substances, the yield of calcium of maple syrup being 1.6 shares and of iron two shares per 100 calories. It is lacking in all vitamins.

Molasses is the mother liquor remaining after the removal of part of the cane sugar from the boiled-down juice of the sugar cane. In addition to the sugar which it contains, it has considerable mineral matter, yielding four shares of calcium, and five shares of iron per 100 calories, but contains no vitamins.

Mixed syrups of various kinds are on the market and their ingredients may be learned from their labels.

Cane sugar resembles fat in being a concentrated form of body fuel, but differs from it in its effect on appetite and digestion. A scant two tablespoonfuls of granulated sugar will yield 100 calories and can be eaten in a meal without adding perceptibly to the volume of food consumed. In a cupful of lemon jelly, nine tenths of the calories come from one fourth of a cup of sugar, and in a cupful of vanilla ice cream nearly half the calories come from two tablespoonfuls of sugar. A cubic inch of chocolate fudge, in spite of milk,

chocolate, and butter, has three fourths of its calories in the form of sugar.

A comparison of the shares of energy, protein, calcium, phosphorus, iron, and vitamins in 100 calorie portions of cane sugar, cane molasses, honey, and dates in Fig. 110 shows the contrast between pure sugar and a sweet dried fruit.

As body fuel, any kind of sugar is interchangeable with starch, calorie for calorie. In the process of digestion, starch

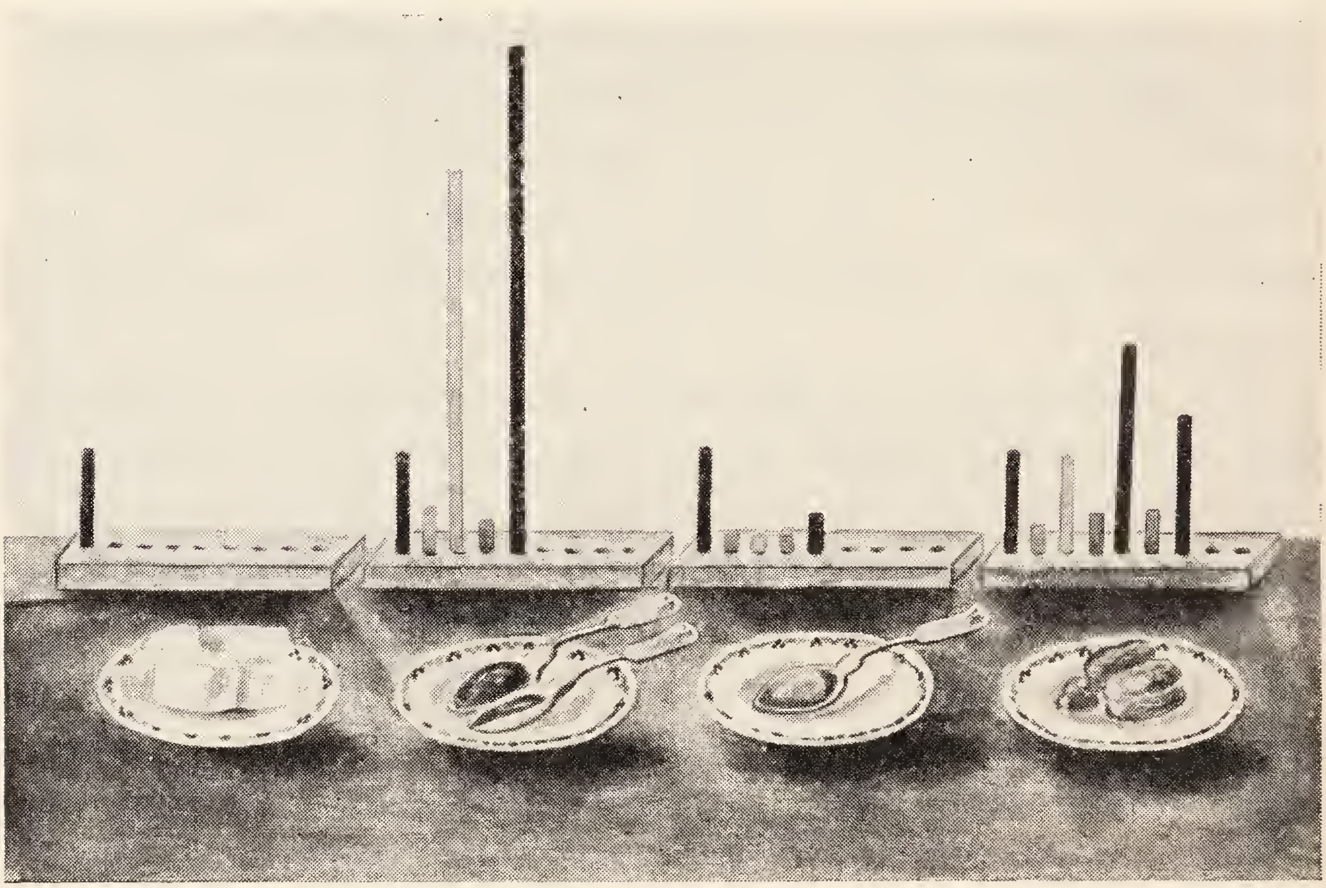

FIG. 110.—A Comparison of the Shares Contributed to the Diet by 100 Calorie Portions of Sugar, Molasses, Honey, and Dates.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Sugar, 4 lumps	1.0	—	—	—	—	—	—	—	—
Molasses, $1\frac{1}{2}$ tbsp.	1.0	0.3	3.9	0.2	5.1	—	—	—	—
Honey, 1 tbsp.	1.0	0.1	0.1	0.1	0.4	—	—	—	—
Dates (4)	1.0	0.2	0.9	0.4	2.1	0.3	1.2		

is converted to sugar and nowadays much cornstarch is turned into glucose (corn syrup) before ever it is eaten. Sugar and starch are both delivered to the blood stream from the alimentary tract as sugar. But no one would agree that starch and sugar are interchangeable in the menu; in

fact we constantly add sugar to starch! The real reason for eating sugar is its sweetness. "Sweeter than honey in the honeycomb" is a time honored phrase of high appreciation. How many things lose their zest when sugar is lacking! Sugarless tea, coffee, cocoa, breakfast cereals, stewed fruits, may still be acceptable to a minority, but cake and cookies, pie and pudding, are unthinkable without sweetness. The bakery, the candy shop, and the soda fountain bear abundant testimony to our love of sweets. Four million tons of cane sugar a year for the American people—over 100 pounds apiece for every one, men, women, children, and infants, or over a quarter of a pound daily—what is it doing to the American dietary?

If too much sugar is allowed to displace other foods the diet will be deficient in the building and regulating materials which sugar lacks utterly. The influence of sugar may be illustrated in the difference in relative food values of a raw apple and the same apple with the sugar usually added in baking. Eating the baked apple may be more enjoyable, but the amount of other dietary essentials obtained in proportion to calories will be only half as much as in the raw apple as the figures on page 442 will show.

To use the least sugar which will produce an acceptable flavor is a good rule. Sugar creates an appetite, not for other foods, but for itself. The candy eater asks for more candy, not for bread and butter; the cake eater scorns the innocuous mildness of junket. Children who are allowed to eat candy whenever they feel like it are likely to be undernourished because the candy spoils their appetite for the foods they need for growth.

Sugar taken alone on an empty stomach is directly irritating to the mucous lining, from which it abstracts water just as a piece of candy held in the cheek causes it to "pucker." Hence the best place for sweet food is at the end of a meal, when it will be diluted, so to speak, by the food already consumed, and when it will not come directly into contact with the stomach wall.

Sugar taken in dilute form, as in sweet fruits, or as a sweetener for the juice of acid fruits like lemon and grapefruit, is not irritating to the stomach, and should be quickly digested and absorbed. For those who engage in severe muscular activity, as athletes, or very active older boys and girls, some sugar taken in this way may be beneficial, especially if the intervals between meals are long.

As commonly used, honey and table syrups are a menace to digestion; i. e., taken freely with butter over hot biscuits,

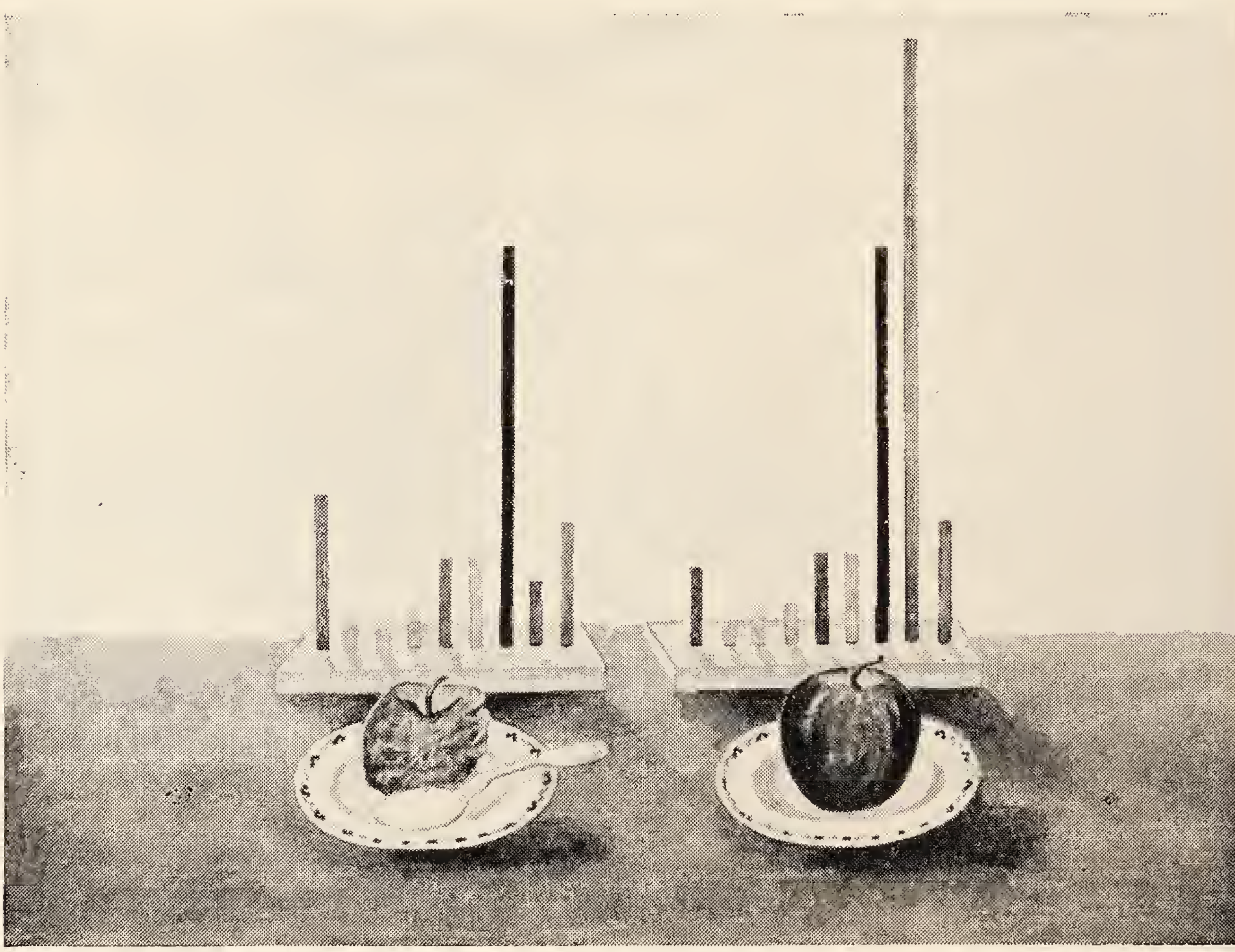

Fig. 111.—Shares Contributed to the Diet by a Raw Apple Compared with Those from an Apple Baked with One Tablespoonful of Sugar.

	Shares in Order on Blocks								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Apple, baked with sugar	1.6	0.2	0.4	0.4	0.9	0.9	3.2	0.6	1.3
Raw apple	0.8	0.2	0.4	0.4	0.9	0.9	3.2	6.4	1.3

griddle cakes, waffles, and the like, such a compound offers every opportunity for irritation of the digestive tract. It is hard to find a place for such foods in a dietetically well managed family, save in the making of plain hard candies

to take the place of soft, rich commercial confectionery. To eat a piece of such candy at the end of a meal is better than deluging food with syrup.

Molasses, carrying significant amounts of calcium, may be chosen as a sweet for growing children in preference to cane sugar or syrups with some advantage, if the amount of milk which can be obtained is not ideal; although it must be remembered that a tablespoonful and a half of molasses will yield only about the same amount of calcium as one and one half cups of carrots diced in half inch cubes. The iron in molasses is high enough to deserve investigation as to its efficiency in nutrition. Hard molasses cookies, especially when made with whole wheat flour or with part of the wheat flour replaced by rolled oats, would seem to be an excellent sweet for children if used in moderation at the end of a meal.

Summary

Fats and sugars are primarily sources of fuel. Milk fat, whether cream or butter, is rich in vitamin A and on this account is of higher value than other food fats. Fat adds to the palatability of food and extends the range of culinary products greatly. It tends to retard digestion somewhat, giving a feeling of satisfaction after eating, but if used in excess, may delay digestion too much.

Sugars and other sweets owe their place in the diet to the popularity of their flavor. Contributing calories only, sugar can be replaced except as regards flavor and the part it plays in various culinary operations. Wise use implies great moderation as to quantity and care as to the time of eating sweets. Light corn syrup and cane sugar yield calories only, but dark corn syrup is a good source of iron and pure molasses is a concentrated vegetable juice, rich in calcium and iron.

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CHAPTER XXII

THE CONSTRUCTION OF AN ADEQUATE DIET: DIETS FOR ADULTS

Many factors enter into the food problem as it appears in everyday life. In the same household there are generally people of different food requirements. The baby cannot be fed like the five-year-old, nor the five-year-old like the high school belle, nor she like her football-playing brother. The dainty fare which best suits the school teacher is held in scorn by the farm laborer whose energy needs are twice as high. To use the same food resources for all and make adjustments which assure each a palatable, digestible, and well balanced diet calls for knowledge and skill in the apportionment of the various items on the menu.

But this is not all. There are other problems arising from the environment. Eating is a social matter. When the family is away for the day, the housemother may be quite content with a luncheon of bread and milk in the kitchen, but when the group returns she feels impelled to put on the dinner table a more imposing array of foods, for dining is a social function important to the higher life of the circle and there is a laudable desire to make the food worthy of the occasion. Furthermore, friends are entertained with food. Seldom is the guest allowed to depart without the hospitable offer of something to eat, not because he needs nourishment, but because this is a form of entertainment held in high esteem. In apportioning the family food money one has to consider in addition to the cost of actual nourishment how much must be added to meet the social ideals of the family itself, and how much for the entertainment of friends according to the standards of the community.

It is not within the scope of this chapter to deal with

the broader social aspects of the food problem. The aim is rather to show how one may use knowledge of body requirements for the various dietary essentials and of the nutritive properties of common food materials to formulate a workable scheme for daily living; steering clear of the Scylla of perpetual calculation or worry and at the same time avoiding the Charybdis of eating according to the whim of the moment regardless of future welfare. Every person should have a simple program to care for routine food needs systematically and effectively. To show how such programs may be formulated and tested is the main object of this chapter.

The analogy between building a diet and building a house is remarkably close. "Specifications" must be furnished by one who understands the whole building process. The man who has money enough goes to an architect and puts the whole matter in his hands. A special plan is made to meet his individual needs. So a man whose life depends upon a diet containing a specified number of grams of protein, fat, and carbohydrate for every meal, with no margin for mistakes or indiscretions, is fortunate if he can put his case into the hands of a professional dietitian who will assume responsibility for all details.

But this specialized service is too costly for the majority. Another way to get a house is to "shop around" for plans of various sorts made by good architects for books or magazines. These can be bought with full specifications at a nominal cost; and if one can be found approximating the builder's ideal it will be far better than an untrained person's plan. Similarly, one may ask a dietitian to make a set of menus and quantitative specifications for a diet to be followed day by day by the person or group for whom it is planned. An institution may have sets of such plans for various seasons of the year, each repeating every three or four weeks. The chief objection is the danger of too great monotony and too little adjustment to individual needs.

There is still a third way of getting a house. Certain firms

supply units already built and easily fitted together and it is possible to select the ones which make the sort of house the buyer wishes. By choosing as many wall units as needed for a house of the desired size, the main outline is determined. One may then pick out any one of several styles of doors and windows, of porches and ells, of dormers for the roof, and assemble them according to his taste. The final result may not be as elegant as if each detail had had individual attention, but the dwelling can be very serviceable and far more artistic than anything an ordinary person would produce by starting with raw materials and evolving his own plan.

We usually build a diet by this third plan. We assemble foods as we would units of a house. We do not buy calories, grams of protein, iron, etc.; we buy meat and potatoes, apples and eggs, which resemble the ells, porches, dormers, etc., of the ready-to-assemble house. With a little study of their characteristics they can be fitted together to make a satisfactory whole, that is, an adequate diet for healthy individuals under ordinary living conditions.

A Diet for an Active Adult at Moderate Cost

We have said in Chapter XVIII that the foods from the cereal grains are primarily valuable as sources of energy, and secondarily as sources of protein; and if germ or bran or both be included, for vitamin B and iron. They are the most economical part of the diet, and the proportion used depends largely upon the amount of money available for food. As much as one half of the total calories of an adult man may be secured from this group of foods, but if over one third of the total comes from this group, special emphasis should be placed on the use of the grains with the bran and germ retained, since otherwise the burden of furnishing minerals and vitamins and laxative properties will fall too heavily on the rest of the diet.

Milk has been shown to be a great protector of the diet at almost every point; of unique importance for calcium,

phosphorus, and other mineral elements, and for vitamins A, B, and G. Even in the adult diet, therefore, a liberal amount of milk should be included at all times. At least a pint a day is a good rule, with increase to a quart as optional but desirable. This means a minimum of about 12 per cent of the total calories of the diet from milk and a maximum of approximately 20 per cent according to the fuel value of the diet; 12 per cent of 3,000 calories would be nearly a pint, but it would take 18 per cent of 2,000 calories to get this amount.

Vegetables and fruits deserve a definite place in the diet because of the mineral salts and vitamins which they can furnish, and also because of their laxative properties. Green vegetables, carrots, tomatoes, and citrus fruits are particularly valuable, and should be used frequently. At least 12 per cent of the total calories should come from an assortment of fruits and vegetables and, unless cost is prohibitive, this group should contribute from 15 to 20 per cent of the total calories.

Fats and oils, whose value for flavor and "staying power" as well as their high number of calories per pound makes them important in a well balanced diet, may contribute from 10 to 20 per cent of the total calories. When other sources of vitamin A are limited, it is desirable that much of the fat be butter unless cod liver oil is used regularly, in which case vitamin A will be amply furnished. It is not wise to purchase butter to the exclusion of milk and green vegetables, and some other fat, supplemented by cod liver oil, might be cheaper than butter and in combination furnish more of vitamins A and D.

Sugars, while adding much to the palatability of the diet contribute fuel only and must not constitute a high proportion of the total calories or there will be danger of shortage of ash constituents and vitamins; and also of digestive disturbances. From 10 to 12 per cent of the total calories from sugar is usually satisfactory for an adult dietary.

The amount of eggs, meat, and other flesh foods to be

used is determined partly by their nutritive value, partly by their flavor and ease of preparation for the table, and partly by cost. As has already been shown in Chapter XX, meats are relatively expensive in comparison with their nutritive return. To get a good diet at low cost, it is best to increase the milk and decrease the meat. Eggs give a higher nutritive return than meat, being rich in vitamins A, B, D, and G, while ordinary muscle meat with the exception of pork, which is high in vitamin B, is poor in vitamins A, B, and D although an excellent source of vitamin G. This and valuable mineral content make it desirable that part of the calories allotted to this group come from eggs. Ordinarily the group allotment should not exceed 15 per cent of the total calories, and in very economical dietaries it will be less than 10 per cent.

A good diet at moderate cost can be readily constructed, using the following plan for the general distribution of calories:

		Per Cent
I.	Foods from the cereal grains (including bread, crackers, macaroni, rice, etc., as well as breakfast foods)	30
II.	Milk	13
III.	Vegetables and fruits of at least three kinds	15
IV.	Fats and oils (such as butter, cream, oil, suet, bacon, etc.)	17
V.	Sugars and foods very rich in sugar (such as jellies and jams)	10
VI.	Eggs, cheese, meat, and other flesh foods	15
	Total	100

Applying this plan to a particular case, we may take a man of average weight (70 kilograms or 154 pounds) leading a fairly active life as a civil engineer, and needing about 40 calories per kilogram per day or a total of 2,800 calories. A balanced diet for him would therefore be represented by 28 shares each of calories, protein, calcium, phosphorus, iron, and vitamins A, B, C, and G. Taking our 28 energy shares, we may allot them to the different food groups according to our plan for the distribution of calories in the diet as follows:

Distribution of Calories and Calorie Shares in a Diet of Moderate Cost

Class of Food	Per Cent of Total Calories	Calorie Shares per Day
I. Foods from cereal grains	30	8.4
II. Milk	13	3.6
III. Vegetables and fruits	15	4.2
IV. Fats and oils	17	4.8
V. Sugars, syrups, preserves, etc.	10	2.8
VI. Eggs, cheese, meat, and other flesh foods	15	4.2
Total	100	28.0

It will be no difficult task with this plan in hand to select foods for a day's menu. First we may choose our cereal foods, 8.4 shares. Two servings of a breakfast cereal (e. g., rolled oats) will furnish 1.8 shares and two rolls for dinner two more. Bread will contribute the major portion, so we will allow three half-inch slices for toast for breakfast; three to be eaten with the noon meal; and two to be used in cooking dinner at night, making a total of four shares. Thus we have provided 7.8 shares. The remaining 0.6 may come from flour to use in cooking. The table below shows the selection of foods for the whole day.

Selection of Food Materials for a Moderately Priced Diet

Class of Food	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Foods from cereal grains	8.4	Rolled oats (cooked)	$1\frac{1}{3}$ cups	1.8
		Bread, white	8 half-inch slices $3\text{x}3\frac{1}{2}$ inches	4.0
		Rolls	2 rolls	2.0
		Flour	2 scant tbsp.	0.6
II. Milk	3.6	Whole milk	$2\frac{1}{6}$ cups	3.6
III. Vegetables and fruits	4.2	Oranges	1 medium	0.8
		Apples	1 medium	0.8
		Potatoes	2 medium	2.0
		Tomatoes	$\frac{1}{2}$ cup	0.3
		Lettuce	$\frac{1}{2}$ head	0.3
IV. Fats and oils	4.8	Butter	4 tbsp.	4.3
		Olive oil	$\frac{1}{2}$ tbsp.	0.5

Selection of Food Materials for a Moderately Priced Diet—*Continued*

Class of Food	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
V. Sugars and syrups, preserves, etc.	2.8	Cane sugar	$5\frac{1}{3}$ tbsp.	2.8
VI. Eggs, cheese, meats, and other flesh foods	4.2	Lean beef (cooked)	$2\frac{1}{2}$ oz.	2.0
		Ham, lean	1 oz.	1.0
		Eggs	$1\frac{1}{2}$ eggs	1.2

Taking the above list of foods and referring to Table I in the Appendix, we can find the contribution to the diet of each item as follows:

A Moderately Priced Dietary

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Rolled oats, cooked	$1\frac{1}{3}$ cups	1.8	3.0	1.3	4.0	4.3	—	6.3	—	+
Bread and rolls	8 slices 2 rolls	6.0	8.4	2.9	4.8	4.2	—		—	
Flour, white	2 tbsp. (scant)	0.6	0.8	0.1	0.4	0.3	—	—	—	—
Milk, pasteurized	$2\frac{1}{6}$ cups	3.6	6.8	26.6	11.0	2.5	10.8	5.8	5.8	7.9
Oranges	1 med.	0.8	0.6	1.8	0.7	1.7	1.0	11.6	47.2	2.5
Apples	1 med.	0.8	0.2	0.5	0.3	0.9	1.0	3.2	6.4	1.3
Potatoes	2 med.	2.0	2.1	1.2	3.1	4.3	0.6	9.6	13.0	3.0
Tomatoes	$\frac{1}{2}$ cup	0.3	0.7	0.6	1.0	1.3	11.4	5.1	25.5	1.5
Lettuce	$\frac{1}{2}$ head	0.3	0.8	1.3	1.6	1.8	2.2	6.5	6.0	2.2
Butter	4 tbsp.	4.3	0.4	0.5	0.3	0.3	21.9	—	—	—
Olive oil	$\frac{1}{2}$ tbsp.	0.5	—	—	—	—	—	—	—	—
Sugar	$5\frac{1}{3}$ tbsp.	2.8	—	—	—	—	—	—	—	—
Beef, round, lean, cooked	$2\frac{1}{2}$ oz.	2.0	10.9	0.7	6.0	7.6	0.8	4.8	—	6.4
Ham, lean	1 oz.	1.0	3.0	0.4	1.3	1.1	+	+	—	+
Eggs	$1\frac{1}{2}$ eggs	1.2	4.3	2.2	4.1	4.7	16.1	4.7	—	5.9
Total		28.0	42.0	40.1	38.6	35.0	65.8	57.6	103.9	30.7
Standard		28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0

By comparison of these results with our standard we see that our selection of foods has given us ample protection at every point with regard to which calculations have been made.

Vitamin A is generously supplied, as the dietary furnishes at least 66 shares, three fourths from milk, butter, and eggs and one fourth from tomatoes and lettuce. Vitamin C is ample, approximating 100 shares, over three fourths from oranges and tomatoes. Vitamin G is furnished to the extent of at least 30 shares, one fourth from milk, and one half from eggs, lettuce, and beef together. Vitamin B is about as generously supplied as vitamin A.

The man for whom it is proposed will probably be most interested in knowing whether this selection of food "on principle" will make him an acceptable series of meals for the day. There are many possible combinations of any such assortment of foods, but the following shows what can be done with the present selection:

A Day's Menu for a Moderately Priced Diet

Breakfast: Orange
Rolled oats, 1⅓ cups; milk, 1 cup; sugar, 1 tbsp.
Toast (3 slices bread); butter, 1 tbsp.
Coffee; top milk, 2 tbsp.; sugar, 1 tbsp.

Luncheon: Broiled ham
Creamed potatoes with 1 hard boiled egg (using flour, ¼ cup milk, and 1 tbsp. butter)
Bread, 3 slices; butter, 1 tbsp.
Apple Betty (using the apple, 1 slice bread, 2 tbsp. sugar, and ½ tsp. butter and serving with ⅓ cup milk)

Dinner: Round steak
Baked potato; butter, 1 tbsp.
Scalloped tomatoes (using 1 slice bread, 1 tsp. sugar, and ½ tsp. butter)
Lettuce and French dressing (using the olive oil)
Rolls, 2
Bread pudding (using ½ cup milk, 1 slice bread, ½ egg, and 1 tbsp. sugar)

It must never be forgotten that the administration of a diet is quite as important as the plan upon which it is built. Just as the work of the architect is only begun when the plans are drawn and must continue until he has accomplished the greater task of finding the materials and the workmen to translate his paper house into a worthy edifice,

so the dietitian must select foods with reference to good quality and fair price, must see that they are cooked so that their nutritive values are conserved or enhanced and not depreciated, and must combine them into meals which are satisfying and wholesome. Furthermore, these meals must be served with regularity from day to day, so that the human machine may run smoothly, without wrench or strain so far as food is concerned. For a fuller discussion of the care of the digestive mechanism and adjustment to various problems related to feeding adult men and women the reader is referred to *Feeding the Family*. The following suggestions for the making of a good menu are taken from Rose's *Laboratory Handbook for Dietetics*, 4th edition, page 43:

"1. Conceive of the whole day as a unit, rather than the individual meal.

"2. Endeavor to distribute the protein, fat, and carbohydrate through the day, so that no meal will have a striking preponderance of one kind of foodstuff.

"For example, meat served with macaroni and cheese concentrates the protein in one meal, potatoes with rice concentrate the starch, and fried potatoes and pie concentrate the fat.

"3. With the exception of a few such staples as bread, butter, and milk, try to avoid serving any food in the same form twice in the same day and serve it preferably only once in any form.

"4. It makes food more interesting to avoid serving any food which gives character to a dish twice in the same meal, even in different forms. Do not, for instance, select tomato soup and tomato salad for the same meal.

"5. At each meal, seek contrasts between successive courses, a bland course being followed by a more highly flavored course, and vice versa, to give a pleasing rhythm.

"6. In each course pay attention to flavor, color, form, and texture. There are esthetic values in crisp crackers with soup, a green lettuce leaf on a salad plate, a red cherry on a rice pudding, a gelatin jelly turned from a graceful mould,

or a slice of lemon with a serving of fish, and other combinations which exhibit pleasing contrasts.

"7. As the number of courses increases, decrease the number of dishes and size of the servings in each."

A Diet for an Active Adult at Minimum Cost

For an adequate diet for an adult at minimum cost, cereal foods must be made as appetizing as possible, and must be made the carriers not only of calories and considerable protein, but also of iron and vitamin B. Consequently the major portion of the cereal foods should be from the grain without removal of the bran nor the germ. A plan for the distribution of calories in an adult dietary of minimum cost is given below, and also for comparison a plan for one which is rather expensive owing to the small dependence put upon the grain foods, and the large proportion of fruits and vegetables.

Distribution of Calories in Diets of Low and High Cost

Class of Food	Low Cost Percentage of Total Calories	High Cost Percentage of Total Calories
I. Foods from cereal grains (including bread, crackers, macaroni, rice, etc., as well as breakfast cereals)	40	20
II. Milk	18	16
III. Vegetables and fruits	12	20
IV. Fats and oils	12	18
V. Sugars, syrups, etc.	10	10
VI. Eggs, cheese, meat, and other flesh foods	8	16
Total	100	100

The man doing hard physical labor is generally the one who must consider most carefully the cost of his calories, since he needs so many of them. Instead of applying the above plan to a day's ration for a professional man with a moderate energy requirement, we may better apply it to a carpenter needing perhaps 30 shares per day.

Expressed in shares our distribution of calories will now be:

Distribution of Calories in a Low Priced Dietary

Class of Food	Percentage of Total Calories	Shares per Day
I. Foods from cereal grains	40	12.0
II. Milk	18	5.4
III. Vegetables and fruits	12	3.6
IV. Fats and oils	12	3.6
V. Sugars, syrups, etc.	10	3.0
VI. Eggs, cheese, meat, and other flesh foods	8	2.4
Total	100	30.0

Selection of Food Materials for a Low Priced Diet

Class of Food	Shares Required	Food to Yield Shares Required	Measure of Food	Number of Shares
I. Foods from cereal grains	12.0	Bread, whole wheat	¾ lb.	9.0
		Farina (cooked)	2¼ cups	3.0
II. Milk	5.4	Milk, whole	3 cups	5.4
III. Vegetables and fruits	3.6	Beans, navy	⅙ cup	1.0
		Tomatoes, canned	1 cup	0.6
		Potatoes	1 large	1.6
		Cabbage, shredded	2 cups	0.4
IV. Fats and oils	3.6	Pork fat	1 tbsp.	1.0
		Butter	2 tbsp.	2.0
		Beef fat	½ tbsp.	0.6
V. Sugars, syrups, etc.	3.0	Molasses	1½ tbsp.	1.0
		Cane sugar	2 tbsp.	2.0
VI. Meat, eggs, cheese, etc.	2.4	Cheese, American	1⅛ in. cube	1.0
		Beef, rump	2½ oz.	1.4
Total				30.0

It will be interesting to test this plan as we did the former one to see whether it is adequate in protein, ash constituents, and vitamins, hence a dietary based on it follows on page 456. A comparison of this with the more expensive one on page 451 will show that the two are almost equally protected at every point. In this cheaper one full protection is achieved mainly by the selection of whole wheat bread, the use of navy beans whose nutritive value is high in proportion to cost, and the inclusion of a liberal supply of milk.

Vitamin A is not quite so liberally provided, but is still

A Low Priced Dietary

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, whole wheat	¾ lb.	9.0	14.2	3.1	12.7	11.7	—	54.9	—	+
Farina, light, cooked	2¼ cups	3.0	3.7	0.8	2.4	1.3	—	—	—	—
Milk, pasteurized	3 cups	5.4	10.3	40.0	16.5	3.8	16.2	8.6	9.4	12.5
Beans, navy, dried	⅙ cup	1.0	2.6	1.9	3.0	5.8	0.2	7.3	—	+
Tomatoes	1 cup	0.6	1.4	1.3	1.9	2.6	22.9	10.2	51.0	2.9
Potatoes, boiled	1 large	1.6	1.7	0.9	2.5	3.5	0.5	7.7	10.4	2.4
Cabbage, shredded	2 cups	0.4	0.8	2.5	1.0	1.1	0.8	6.4	35.0	3.2
Pork fat	1 tbsp.	1.0	—	—	—	—	—	—	—	—
Butter	2 tbsp.	2.0	0.1	0.2	0.1	0.1	10.2	—	—	—
Beef fat	½ tbsp.	0.6	—	—	—	—	—	—	—	—
Molasses, cane	1½ tbsp.	1.0	0.3	3.9	0.2	5.1	—	—	—	—
Cane sugar	2 tbsp.	2.0	—	—	—	—	—	—	—	—
Cheese, American	1⅛ in. cube	1.0	2.6	9.2	3.6	0.6	5.8	+	—	2.3
Beef, rump	2½ oz.	1.4	5.7	0.3	3.6	4.3	0.6	3.4	—	4.5
Total		30.0	43.4	64.1	47.5	39.9	57.2	98.5	105.8	27.8
Standard		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

nearly double the standard and so conforms to Sherman's suggestion of at least four times requirement to get the fullest protection. Vitamin B is much more liberally provided owing to the large amount of bread from whole wheat, which furnishes nearly two thirds of the vitamin. The use of tomatoes, such an excellent source of vitamin C, gives assurance of a good supply. In using other vegetables, where the number is limited, care should be taken to have one very good source of vitamin C besides potatoes. It will be noted that the milk is the most important source of vitamin G, furnishing nearly half of the total supply. Judging from available data on Lima beans, the navy beans should furnish enough to raise the total above requirement.

A menu illustrating the practical use of this more limited

assortment of food materials is perforce simpler than one for which a larger number of kinds of food has been used, and bread is the chief staple in every meal.

A DAY'S MENU FOR A LOW PRICED DIET

Breakfast:	Farina with $1\frac{1}{2}$ cups milk and 1 tbsp. sugar
	Whole wheat bread, $\frac{1}{4}$ lb. with molasses and coffee
Luncheon:	Baked beans with pork fat
	Whole wheat bread, $\frac{1}{4}$ lb.
	Cheese
	Milk, $\frac{1}{2}$ cup in coffee
Dinner:	Beef stew with potato, tomato, and beef fat
	Raw cabbage
	Whole wheat bread, $\frac{1}{4}$ lb.

A Diet for a Sedentary Adult

The plans so far suggested have been for persons leading a life in which most of the working day is spent in at least moderate muscular activity, as walking, clambering about, lifting fairly heavy materials, and the like. But in a modern city, one may ride to work, sit all day at one's desk, or engage in no muscular activity greater than standing or walking slowly about from time to time, have luncheon in the building in which one works, ride home at night, sit down to dinner, and afterwards spend the evening sitting, whether reading at home, attending the theater, or enjoying a game of bridge. How many calories can be spent under these circumstances? And what changes in the program do a lower calorie income necessitate?

The first thing to remember is that *the only item to be reduced is the total calories*. Everything else must be as liberal as suggested for active adults. Looking at the plan for distribution of calories on page 449 we may ask what groups, if any, yield calories and little else? Obviously, two of them, Group V (sugars and sweets which are mostly sugar), and Group I, so far as the cereal foods are highly milled products (such as white bread, macaroni, flour, starch, cereal breakfast foods without bran and germ), can both be reduced without

decreasing minerals and vitamins. Group IV also needs to be reduced, since the fats are weight for weight two and one fourth times as good sources of calories as the starches and sugars. Although this group will include carriers of vitamin A, such as butter, it should still be reduced for the vitamin A can be obtained with few or no calories by the addition of cod or halibut liver oil or a cod liver oil concentrate. A good program for a low calorie diet will then have a distribution of the following type:

Distribution of Calories and Calorie Shares in a Dietary for a Sedentary Adult

Class of Food	Per Cent of Total Calories	Calorie Shares per Day
I. Foods from cereal grains	15	3.3
II. Milk	25	5.5
III. Vegetables and fruits	25	5.5
IV. Fats and oils	10	2.2
V. Sugars, syrups, preserves, etc.	5	1.1
VI. Eggs, cheese, meat, and other flesh foods	20	4.4
Total	100	22.0

Selection of Food Materials for a Diet for a Sedentary Adult

Class of Food	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Foods from cereal grains	3.3	Bread, whole wheat	4 slices	2.0
		Roll, white	1 roll	1.0
		Flour	1 scant tbsp.	0.3
II. Milk	5.5	Whole milk	$3\frac{1}{3}$ cups	5.5
III. Vegetables and fruits	5.5	Potatoes, cooked	1 large	1.6
		Cauliflower, cooked	$\frac{1}{3}$ head	0.4
		String beans, cooked	$\frac{1}{2}$ cup	0.3
		Lettuce	$\frac{2}{5}$ head	0.2
		Celery	$1\frac{3}{4}$ oz.	0.1
		Orange juice	$\frac{3}{4}$ cup	1.0
		Peaches	2 medium	1.0
		Watermelon	$\frac{3}{4}''$ slice	0.9
IV. Fats and oils	2.2	Butter	2 tbsp.	2.2
V. Sugars	1.1	Sugar, cane	1 tbsp.	1.1
VI. Eggs, cheese, meats	4.4	Beef, lean	$2\frac{1}{2}$ oz.	2.0
		Chicken	3 oz.	1.7
		Egg	1 egg	0.7

Selection of food materials is now a comparatively simple matter, and from a wide choice of available foods we may perhaps choose those shown in the preceding table.

That this selection of foods will meet the requirements is shown by the following dietary.

DIETARY FOR A SEDENTARY ADULT

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, whole wheat	4 slices $\frac{1}{4}''$ thick	2.0	3.2	1.8	2.8	2.6	—	12.2	—	+
Rolls	1 roll	1.0	1.4	0.5	0.9	0.7	—	—	—	—
Flour	1 tbsp. (scant)	0.3	0.4	—	0.2	0.2	—	—	—	—
Milk, pasteurized	$3\frac{1}{3}$ cups	5.5	10.4	40.7	17.1	3.8	16.5	8.8	9.6	12.7
Potatoes, cooked	1 large	1.6	1.7	0.9	2.5	3.5	0.5	7.7	10.4	2.4
Cauliflower, cooked	$\frac{1}{3}$ head	0.4	1.1	7.0	1.8	2.5	0.6	6.8	6.4	4.0
String beans, cooked	$\frac{1}{2}$ cup	0.3	0.7	1.7	0.9	1.7	7.2	2.4	3.3	0.9
Lettuce	$\frac{2}{5}$ head	0.2	0.5	0.9	1.1	1.2	1.4	4.4	5.0	1.4
Celery	$1\frac{3}{4}$ oz.	0.1	0.3	1.7	0.6	0.6	—	+	2.5	—
Orange juice	$\frac{3}{4}$ cup	1.0	0.4	1.5	0.5	0.9	1.3	14.6	59.5	3.2
Peaches, yellow	2 medium	1.0	0.4	0.9	1.0	1.3	39.2	+	9.0	
Watermelon	1 slice $\frac{3}{4}''$ thick	0.9	0.5	1.1	0.9	1.4	2.7	5.0	20.7	1.8
Butter	2 tbsp.	2.2	0.1	0.2	0.1	0.1	11.2	—	—	—
Sugar	1 tbsp.	1.1	—	—	—	—	—	—	—	—
Beef, round, lean, cooked	$2\frac{1}{2}$ oz.	2.0	10.9	0.7	6.0	7.6	0.8	4.8	—	6.4
Chicken, boiled	3 oz.	1.7	9.0	0.5	5.3	4.4		+	—	+
Egg	1 egg	0.7	2.5	1.3	2.4	2.7	9.4	2.7	—	3.4
Total		22.0	43.5	61.4	44.1	35.2	90.8	69.4	126.4	36.2
Standard		22.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

Without departing from a common plan of food selection, a diet of excellent quality has been achieved. Instead of the whole wheat bread a similar amount of white bread might have been used, and a small portion of wheat germ added to the breakfast to supply the vitamin B, or a little dried yeast taken in the form of tablets if preferred. A

single capsule of halibut liver oil will give ample protection for vitamin A. That such a selection of foods will make an acceptable menu is shown below.

Menu

Breakfast	*Luncheon*	*Dinner*
Orange juice	Chicken, creamed	Lean beef
2 thin slices toast	String beans	Potato
Coffee with top milk and 1 tsp. sugar	Celery	Cauliflower
Egg	1 thin slice bread with 1 tsp. butter	1 thin slice bread with 1 tsp. butter
$\frac{3}{4}$ cup milk	$\frac{3}{4}$ cup milk	$\frac{3}{4}$ cup milk
	Peaches	Lettuce
	Tea if desired	Watermelon
		Coffee if desired

A Diet for an Overweight Adult

The tendency to store fat increases as men and women grow older. It varies with individuals, and if hereditary, needs to be carefully watched. It is easier to begin a program of dietary control which is preventive of overweight than to take off extra pounds of fat which should not have been allowed to accumulate. Some of the problems of surplus calories have been discussed in Chapter VI. Here an attempt will be made to show how modern knowledge of nutrition makes it possible to adjust one's energy intake to one's energy needs without any failure to meet one's other dietary needs. In fact, the good reducing diet is the best in the world in its quality if rightly chosen. The aim is to provide every essential but calories generously—one might almost say luxuriously, and remember that the reason calories can be limited is that there are plenty of calories in the body fat, which will not be used if a plentiful supply comes in with every meal.

A working plan will reduce the foods furnishing calories only somewhat more than in the plan where the object is merely to keep in calorie balance when one is not much of a calorie spender. The following distribution of calories will furnish the basis for food selection.

Distribution of Calories and Calorie Shares in a Dietary for an Overweight Adult

Class of Food	Per Cent of Total Calories	Calorie Shares per Day
I. Foods from cereal grains	10	1.3
II. Milk	30	3.7
III. Vegetables and fruits	32	4.0
IV. Fats and oils	8	1.0
V. Sugars, syrups, preserves, etc.	0	0.0
VI. Eggs, cheese, meat, and other flesh foods	20	2.5
Total	100	12.5

With this plan to guide us, we can choose foods according to preference, for each food group, as the following selection indicates.

Selection of Food Materials for a Diet for an Overweight Adult

Class of Food	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Foods from cereal grains	1.3	Bread, whole wheat	2 thin slices	1.0
		Bran, prepared	$\frac{1}{3}$ cup	0.3
II. Milk	3.7	Milk, skimmed	3 cups	2.7
		Cream, thin	$\frac{1}{4}$ cup	1.0
III. Vegetables and fruits	4.0	Potato, cooked	1 medium	1.0
		Carrots, cooked	$\frac{1}{3}$ cup cubes	0.2
		Lettuce	$\frac{2}{5}$ head	0.2
		Peas, cooked	$\frac{1}{4}$ cup	0.3
		Orange juice	$\frac{3}{4}$ cup	1.0
		Banana	1 medium	1.0
		Blueberries	$\frac{1}{2}$ cup	0.5
IV. Fats and oils	1.0	Butter	1 tbsp.	1.0
V. Sugars	0.0	None	—	0.0
VI. Eggs, cheese, meats, and other flesh foods	2.5	Beef, lean, cooked	$2\frac{1}{2}$ oz.	1.8
		Egg	1 egg	0.7

It will be noted that to get as much nutritive value with the fewest possible calories from milk, skim milk is selected instead of whole milk. This gives more opportunity for the enjoyment of a variety of foods, and the vitamin A which would have been obtained from the whole milk is best secured from a very concentrated source, such as halibut

liver oil or a fish liver oil concentrate, or even pure carotene in oil. Since cream is a food which often adds much to the enjoyment of something else, a small quantity of thin cream has been included. It will count for more in the menu separated from the milk than it would if whole milk were taken. The vegetables chosen are excellent sources of vitamins, but could be replaced by larger quantities of leafy vegetables. In fact all green vegetables and all succulent ones such as celery and tomatoes can be added to the diet *ad libitum* if no fats are added to season them, as their calorie value is so low. Salad dressing of excellent flavor can be made with mineral oil, which yields no calories. Orange juice yields more calories than tomato juice or grapefruit juice which can be substituted at pleasure and used in larger measure. When sweetening of grapefruit juice is desired, saccharin which yields no calories, can be used instead of sugar. A little fat helps to give the diet staying power as well as enhancing the attractiveness of such foods as bread and potatoes. The more flavorful whole grain breads are the better choice, though the amount of bread must be so limited that the kind is not very important—in strong contrast to the economical diet for an active adult! The vitamin B without the calories should be obtained from the bran and germ, or some other special source of this vitamin. Sugar gives nothing but calories and is best avoided, as sweetening can be accomplished with saccharin and a person who needs a low-calorie diet should cultivate the habit of enjoying other flavors. Meats should be lean. Many calories are concealed in the fat of a sirloin steak or a pork chop. The all-round value of the egg is high in proportion to its calories, so that it is an excellent staple in a reducing diet.

What kind of nutritive return one can have on such a choice of common foods is shown in the dietary which follows.

Dietary for an Overweight Adult

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, whole wheat	2 thin slices (¼″)	1.0	1.6	0.9	1.4	1.3	+	6.1	—	+
Bran, prepared	⅓ cup	0.3	1.1	1.0	4.0	6.6	—	3.1	—	+
Milk, skimmed	3 cups	2.7	10.0	38.9	16.2	3.8	0.2	8.1	8.6	11.9
Cream (18.5%)	¼ cup	1.0	0.5	2.2	1.0	0.2	3.8			
Potato, cooked	1 medium	1.0	1.1	0.6	1.5	2.2	0.3	4.8	6.5	1.5
Carrots, cooked	⅓ cup cubes	0.2	0.2	0.9	0.4	0.5	13.7	2.2	1.4	1.1
Lettuce	⅖ head	0.2	0.5	0.9	1.1	1.2	1.4	4.4	5.0	1.4
Peas, cooked	¼ cup	0.3	0.8	0.3	0.9	1.2	3.0	6.8	5.4	1.5
Orange juice	¾ cup	1.0	0.4	1.5	0.5	0.9	1.3	14.6	59.5	3.2
Banana	1 medium	1.0	0.5	0.4	0.7	1.3	2.4	2.9	8.5	1.5
Blueberries	½ cup	0.5	0.2	0.8	0.4	1.3	0.2		5.5	0.2
Butter	1 tbsp.	1.0	0.1	0.1	0.1	0.1	5.1	—	—	—
Beef, lean, cooked	2½ oz.	1.8	9.9	0.7	5.4	6.8	0.7	4.4	—	5.8
Egg	1 egg	0.7	2.5	1.3	2.4	2.7	9.4	2.7	—	3.4
Total		12.7	29.4	50.5	36.0	30.1	41.5	60.1	100.4	31.5
Standard		12.5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

A menu illustrating the use of this dietary is shown below.

Menu

Breakfast

Orange juice
Bran with ½ cup milk
1 slice whole wheat toast with 1 tsp. butter
Egg
Coffee with cream
1 haliver oil capsule

Luncheon

Banana
Milk—2 cups
1 slice bread with 1 tsp. butter

Dinner

Beefsteak
Potato, baked with 1 tsp. butter
Carrots and peas
Lettuce with French dressing
Blueberries and ½ cup milk
Coffee with cream

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CHAPTER XXIII

FOOD NEEDS OF PRE-SCHOOL AND KINDERGARTEN CHILDREN

During the last half century there have been real gains in prolonging human life and preventing ill health. In New York City in 1875 the death rate was 28.3 per 1,000; by 1932 it had been reduced to 10.3. The average life span in the city in 1880 was about 40 years; it is now close to 60 years. This improvement has been brought about by a great extension of the application of modern scientific knowledge to the public health problem. Sanitary science has conquered many infectious diseases and protected food and water supplies; the recent rapid growth of the science of nutrition has revealed the full measure of control which diet exercises over life and health. "We have learned," says Dr. Charles H. Mayo, "that the growth of microbes resembles the growth of seed and must have a soil adapted to it, which may have to do with age, degeneration, inherited traits, and changes due to food. Thus in the last five years we have paid more attention to dietetics than ever before, and have come to believe that there is a great deal of truth in the statement that a man digs his grave with his teeth."

We have as yet no impressive mass of data to prove that improvements in diet are contributing directly to the prevention of sickness and the extension of efficient living. It will take wide adoption of the modern principles of nutrition and carefully controlled observations covering many years to make an impressive demonstration of the improvement in human life which can be achieved by a good dietary consistently eaten from birth to old age. But we do have the conquest of goiter and cretinism, of beriberi and pellagra,

of scurvy and rickets, wherever these have been scourges, as evidence that an adequate diet is a real factor in public health; and from the nutrition laboratory we have abundant proof that starting with a diet already good, we may by making it still better, produce in successive generations of animals living in exactly the same environment, a distinctly higher degree of health and vigor.

No child ever had so good a chance of being well born as one entering the world in the twentieth century. Down to the nineteenth century babies seemed born to die, for at least a quarter of them failed to survive the perilous first year. But today the infant mortality in most American communities has been reduced to less than 6 per cent, and there is a good prospect that in the near future two thirds of these deaths will be prevented. Now that sanitary science has conquered many children's diseases and made safe the food supply, the application of our present knowledge of nutrition is more important than ever, to insure to these "saved" babies normal growth from birth to maturity and attainment of such physical vigor as shall make their adult years long and fruitful. "Where vitality exists," says Bertrand Russell, "there is pleasure in feeling alive. It makes it easy to take an interest in whatever occurs, and thus promotes objectivity, which is an essential of sanity. Vitality promotes interest in the outside world; it also promotes the power of hard work."

The period of infancy presents a highly specialized feeding problem and we shall temporarily pass over this, returning to it after discussing the dietary needs of the little child who has passed the period of transition from mother's milk to an independent dietary, but is still in the home and fed according to the needs of his age. In the United States where the food supply is so well protected and knowledge of infant care is free for the asking,[1] a child becomes independent of

[1] Three excellent pamphlets by Mrs. Max West, *Prenatal Care*, *Infant Care*, and *Child Care* are free for the asking from the Children's Bureau, United States Department of the Interior, Washington, D. C.

his mother's milk usually towards the end of his first year, but he is still in the period when growth is very rapid and sensitiveness of the digestive tract great. His food is a tremendously significant factor in his progress at this time, when his only business in life is to grow. The quantitative food requirements for children of various ages have already been discussed under each type of dietary essential. It remains now to see how such knowledge is applied to the everyday feeding problem.

Section 1

THE ONE-YEAR-OLD CHILD

A year-old-baby of average size will require from 900 to 1,100 calories per day, the precise amount varying according to body weight and amount of activity. The large, vigorous, active child will require more total food than the small, delicate, less strenuous one. The energy requirement from day to day cannot be foretold exactly; the regular weighing of the child week by week, and comparison of his rate of progress with our best normal averages is the best criterion of the adequacy of the food supply. But an approximation of the number of calories required is most useful in planning a good dietary, and such increases or decreases as may be necessary are readily made. Every calorie must be chosen with regard to the growth promoting substances it can furnish and its effect upon the digestive tract. Hence it will be desirable to discuss briefly the kinds of food most appropriate for the pre-school child's diet before considering in detail their quantitative relationships. The evidence that the best foundation for the diet is a quart of clean cow's milk has been summarized in Chapter XVII. This amount of milk will insure adequate protein, calcium, phosphorus, and other essential mineral elements, enough vitamin A for growth, and a very considerable amount of vitamins B and G, all in a form specially easy to digest. For vitamin C it is not wise to depend upon the variable supply even in

fresh milk, but always to use some outstanding source known to digest well, such as orange juice or tomato juice, making a small quantity a regular part of the diet. Two to four tablespoonfuls per day of orange juice (or twice as much tomato juice) are ample as a rule.

A small quantity of egg yolk (at least one teaspoonful) is desirable, for its value in hemoglobin formation and its many other growth promoting qualities including excellent proteins, vitamins A, B, D, and G, considerable phosphorus, and some calcium.

A little green vegetable pulp is also to be included, as a further source of iron and other minerals, vitamins A, B, and G, and for its laxative properties. This should be quickly cooked and put through a coarse sieve or finely chopped and should at first not exceed in quantity 2 level tablespoonfuls, lest it lead to digestive disturbances, which are often insidious and must therefore be sedulously guarded against. Spinach, asparagus tips, and peas are very suitable, singly or in combination, and carrots, though not green, are notable for their high nutritive value. Many varieties are available sifted or chopped, in small cans, prepared especially for infants and young children.

If cow's milk were taken with no other food the proportion of protein would be too high for the best growth, consequently a cereal food should be added, choosing preferably one which yields iron and vitamin B, such as rolled oats or a dark farina or a cereal with added wheat germ. This can be served regularly twice a day if desired, from one fourth to one third of a cup of the cooked cereal in the morning and another similar portion for supper being usually sufficient. Cooked vegetable or ready to eat cereal may be substituted now and then for cooked cereal in the evening meal. A small amount of baked potato is also a desirable food for this age, reinforcing the diet in regard to vitamin C, iron, and other mineral elements.

For the sake of stimulating the circulation in the gums and developing the chewing habit, some dry hard bread or

toast is extremely important, and one or two small slices can be given at each of two meals. A little butter on the bread is permissible, but the ounce and a quarter of butter fat in the quart of whole milk makes much additional fat at this age undesirable. Generally a little prune pulp or apple pulp, put through a sieve and sweetened with the merest trace of sugar, for the sake of palatability, can be used without making the diet too laxative or too difficult to digest, but should be omitted if there is any doubt as to its good effect. There is over an ounce of sugar in the milk and that is plenty for a day.

The diet as outlined above may be used with little change throughout the second year. By the twelfth month cereals may be given unstrained, provided they have been cooked very soft. The milk to drink should never be cold. The quantity of bread may be increased, adding a third slice at the noonday meal. All the bread should be dry and hard. It fails of its main purpose if soft. The egg yolk may be increased to one yolk daily. The white is better reserved for the adult dietary. Vegetables should be cooked quickly till soft and put through a coarse sieve or mashed fine. Those which do not lend themselves to such treatment should be deferred till the child is older. As an alternate to cereal for supper, vegetable pulp may be combined with milk in a cream soup and served with small squares of toasted bread.

A good guide to a well assorted dietary for the one-year-old child may be expressed in terms of the total calories, and will fall within the following limits:

Distribution of Calories for the Diets of Children One Year Old

Class of Food	Per Cent of Total Calories
I. Foods from the cereal grains (mostly whole grains)	10–20
II. Milk, whole	65–75
III. Vegetables and fruits (specially selected)	5–10
IV. Butter	1–3
V. Sugar	0–1
VI. Egg yolk	2–3

Taking for example an allowance for a day of 1,000 calories (or 10 shares) we may proceed to distribute them in the following fashion:

Distribution of Calories and Shares in a Diet for a One-Year-Old Child

Class of Food	Per Cent of Total Calories	Shares per Day
I. Food from cereal grains	16.0	1.6
II. Milk	67.5	6.8
III. Vegetables and fruits	10.0	1.0
IV. Butter	3.0	0.3
V. Sugar	1.0	0.1
VI. Egg yolk	2.5	0.2
Total	100.0	10.0

Selecting from the foods which are regarded as best suited to a child of this age, we shall have some such list as this:

Selection of Food Materials for a One-Year-Old Child's Diet

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Food to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Foods from cereal grains	16.0	1.60	Farina, dark with added wheat germ	½ cup, cooked	0.60
			Bread, whole wheat	2 slices	1.00
II. Milk	67.5	6.75	Milk	1 quart	6.75
III. Vegetables and fruits	10.0	1.00	Orange juice	6 tbsp.	0.50
			Peas, strained, canned	2 tbsp.	0.15
			Potato	½ medium	0.50
			Prunes, strained, canned	1½ tbsp.	0.25
IV. Butter	3.0	0.30	Butter	1 tsp.	0.30
V. Sugar	1.0	0.10	Sugar	⅔ tsp.	0.10
VI. Egg yolk	2.5	0.25	Egg yolk	½ yolk	0.25
Total					10.40

To see whether a diet planned in this way is really adequate or not we may calculate the contribution of each food item as shown in the dietary on the following page.

The standard for a child expressed in shares must have

relatively a higher number of calcium and phosphorus shares than energy shares to make the total calcium and phosphorus approximately one gram per child per day. One share of calcium is 0.023 gram ($\frac{1}{30}$ of an adult man's daily requirement), and 10 shares would be only 0.23 gram, which is insufficient for a child. To get a full gram we shall need 43 shares (one gram divided by the value of one share, 0.023). Similarly, to get one gram of phosphorus, we shall need 23 shares (one gram divided by the value of one share, 0.044).

A Dietary for a One-Year-Old Child

Food Materials	Shares Contributed to the Diet									
	Measure	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Farina, dark with added wheat germ	½ cup	0.60	1.0	0.3	1.5	1.3		9.9		
Bread, whole wheat	2 slices	1.00	1.6	0.9	1.4	1.3	+	6.1	—	+
Milk, pasteurized	1 qt.	6.75	12.8	50.0	20.6	4.7	20.2	10.8	11.7	15.6
Orange juice	6 tbsp.	0.50	0.2	0.8	0.3	0.5	0.7	7.3	30.0	1.6
Peas, strained, canned	2 tbsp.	0.15	0.4	0.1	0.3	1.4	2.0	1.1	1.5	0.4
Potato, cooked	½ medium	0.50	0.5	0.3	0.8	1.1	0.2	2.4	3.3	0.8
Prunes, strained, canned	1½ tbsp.	0.25	0.1	0.2	0.2	1.9	1.5	0.6	0.4	1.0
Butter	1 tsp.	0.30	—	—	—	—	1.5	—	—	—
Sugar	⅔ tsp.	0.10	—	—	—	—	—	—	—	—
Egg yolk	½ yolk	0.25	0.4	0.4	0.9	1.2	2.5	1.2	—	0.8
Total		10.40	17.0	53.0	26.0	13.4	28.6	39.4	46.9	20.2
Standard		10.00	15.0	43.0	23.0	15.0	20.0	20.0	40.0	20.0

This diet is adequate in calories, protein, minerals, and vitamins A, B, C, and G, as can be easily seen from the calculation of the dietary. It is interesting to see that milk is the most significant source of vitamins A, B, and G. The addition of one or two teaspoonfuls of cod liver oil will furnish adequate vitamin D for most normal children and reinforced milk with a guaranteed vitamin D content may be used if desired. The cod liver oil has the advantage of

furnishing additional vitamin A, and the liberal amount of vitamin D needed for the best growth.

The daily program at this age involves three regular meals and one supplementary lunch of milk and bread or cracker; breakfast at some definite time between 7 and 7:30 A. M. according to the habits of the family; the second at 11:30 or 12, and supper at 5:30 or 6 P. M. The extra food will be given in the middle of the afternoon after the noonday nap. Fourteen hours should be allowed for the night's sleep and no little child should be up after 7 P. M.

The food may be distributed through the day as follows:

A Day's Menu for a One-Year-Old Child

7:00 A. M.	Cereal jelly, 2½ tbsp. with ¼ cup of warm milk over it
	Warm milk to drink, ¾ cup
	Bread, 1 slice, stale or toasted, with ½ tsp. butter
9:00 A. M.	Orange juice, 6 tbsp.
12:00 A. M.	Potato, baked, ½ medium with 1 tbsp. milk to moisten
	Pea pulp, 2 tbsp. with a little milk to moisten
	Egg yolk, ½ mixed with the potato or with bread crumbs
	Prune pulp, 1 tbsp.
	Warm milk to drink, ¾ cup
3:00 P. M.	Warm milk to drink, 1 cup
5:30 P. M.	Cereal jelly, 2½ tbsp. with ¼ cup warm milk
	Bread, 1 slice, stale or toasted, with ½ tsp. butter
	Warm milk to drink, 1 cup
	1 teaspoonful of cod liver oil after breakfast and another after the evening meal.

The little child's diet must be administered with scrupulous care. Not only is it ministering to immediate needs for growth, but it is also favorably or unfavorably affecting the digestive tract and eating habits.

Meals must be regular. This is easy to say but very difficult to accomplish, and a rule too often broken by those who have little children in charge. Waiting beyond the regular meal time is likely to bring many undesirable reactions such as irritability, fatigue, loss of appetite, or hurried eating.

The foods which comprise the simple menu should be of the best quality, carefully seasoned, and offered in a way to commend them to the child. By word and action, respect

and enthusiasm for the foods which are desirable for his welfare should be imparted. Always the constructive idea that each food is playing its part in building a healthy, happy child should be kept uppermost.

No child should be pitied because of his simple, wholesome diet. No diet is better than that which adequately sup-

(Courtesy of Captain Donald B. MacMillan and the American Museum Journal)

Fig. 112.—Me-gis-s'oo and Shoo-e-ging-wah are playing with their pet dogs in the July sun at Etah. In the summer months, on days when the wind is not too strong, Eskimo mothers give their babies sun baths on bear- or deerskins stretched on the ground. Needless to say the little people like it, and continue to like it until they are quite big boys and girls.

ports the rapid growth of the early years, and there should be no suggestion of any other possibility than eating it cheerfully at the proper time. Food for the young child is not an amusement but serious business upon which his whole progress in life largely depends. It is not to be expected

that all foods will be equally well received at first. New foods are new lessons. They should not be made too difficult. By giving very small portions at first a ready acceptance of many foods is best built up.

To allow no food between meals should be an absolute rule. Nothing is more ruinous to good appetite, good digestion, and good discipline than food at improper times.

Sweets should be rigorously withheld. They pervert the appetite, and are likely to disturb digestion. There is plenty of sugar in the milk. Only what is absolutely necessary to make apple sauce, junket, or other very simple milk puddings palatable, should be used.

Section 2

NURSERY SCHOOL AND KINDERGARTEN CHILDREN

Imitation plays a large part in the little child's life, and it is much easier for him to eat what is given him when others are doing the same. A few children now have the opportunity of attending nursery schools and in the future undoubtedly more will have a similar privilege. For such children the pre-school period is shortened to a year or so, as sometimes the nursery school admits children under two years of age, though the usual age range is from two to four or five years.

When the children arrive in the morning they should at least have a drink of water. If they have breakfast early, and it fits well with the home schedule, they may instead of water have two to four tablespoonfuls of orange juice diluted with as much water; and since children use up their blood sugar fast, the addition of not more than one teaspoonful of corn syrup or malt food (glucose and dextrin or maltose, never sucrose) should help them to go through the morning with less fatigue. This applies particularly to children under four years of age, but is not disadvantageous for any child of nursery school age. Where the winter season is cloudy, the addition of at least one teaspoonful of cod liver oil to the morning feeding is an additional safeguard, giving vitamin A

as well as vitamin D. If this is given regularly at home, it may not be needed at the school. There must be at all times the closest coördination between the home and school programs.

The Midday Meal at the Nursery School

The noonday meal, taken at the school, affords an unusual opportunity for training in good eating habits. The food must be selected with the greatest care, since the school's responsibility for the well-being of the children is heavy. It must be apportioned as carefully as possible according to the requirements of the individual child, and yet the group spirit must be preserved. A dietitian expert in the training of children as well as in nutrition is essential to the highest success and should have constant oversight during the meal. The ease with which children two to four years old (and sometimes even younger) can adapt themselves to the food régime of the school is abundant proof of the power of *esprit de corps*. Sitting at their little tables with their teachers they eat together in the happiest fashion. Now and then some food seems more of a task than a wee one can accomplish, but helped along by an encouraging word, or perhaps a lift with the spoon, the goal is won; or a wise teacher quietly lightens the task if in her judgment it is too great for the moment. It is highly important that any one who supervises the children's meals have training in nutrition as well as in other phases of child care, so that the child's immediate food needs and his education may be properly related to each other.

Day by day the nursery menu must exemplify the best that is known in regard to child feeding. It affords education for parents as well as children. A good program for the dinner will include:

(1) A baked potato or its equivalent creamed or mashed.

(2) A vegetable rich in mineral salts and vitamins, cooked soft and chopped or mashed. Children of this age can be educated to a considerable range of vegetables, and while a

great variety is not essential to their immediate growth, carrots, spinach, and peas being all that one really would need, it is for the convenience of the home and the future ability of the child to adjust himself easily to all wholesome food that his range should be gradually widened.

(3) The yolk of an egg. While the yolk is more important than the white for the young child, economic considerations do not justify a school in rejecting the white of any egg. Hence a daily average per child of from one half to a whole egg seems best under ordinary conditions. The egg can easily be given scrambled or creamed; it may be mixed with the vegetable or potato, or made into a simple dessert such as boiled (which children seem to prefer to baked) custard, or bread pudding made with a boiled custard. Occasionally the egg may be omitted so that it may be included in the home menu. Veal liver, steamed and put through a food chopper, may be creamed or made into a loaf and served with the vegetables. Creamed fish such as halibut, or a little chopped lean beef may also serve as an egg substitute now and then, about an ounce of any one of these being given to each child. With the exception of liver, meat is too poor in growth promoting properties to be given a place of any prominence in a child's diet. It must never be allowed to displace milk or vegetables but so employed as to increase their consumption.

(4) A full cup of milk at room temperature. This is managed more easily by the children if a small cup is used and refilled. The person in charge has to see to it that each child gets his full share.

(5) A regular portion of hard dry bread to chew. The quantity cannot be very large or it will take the children longer to get through with their meal than they can endure to sit, even in chairs adapted to their size. Half a slice of whole wheat bread thoroughly toasted will serve the purpose very well. Other breads, untoasted, can be used to fill the quota of calories.

(6) For the sake of establishing the habit so desirable later on of eating a certain amount of fresh uncooked vegetable

food, it is permissible to incorporate a very little minced raw vegetable into the diet at this age, using it as a sandwich filling. Carrots and lettuce lend themselves admirably to this use; a little of the carrot top can be chopped in with the carrot itself, and a very little raw apple with the lettuce. The sandwiches are well liked by young children, and in the light of modern knowledge of food values, are an improvement over bread and jelly, jam, or honey. Such use of raw vegetables must not be interpreted as countenancing the indiscriminate use of raw vegetables or fruit at this period. Except as given above, neither is safe for young children. With the exception of orange juice or other mild fruit juice, fruit should generally be cooked, though thoroughly ripe bananas may be cut in small pieces and served with orange juice. The effects of even mild indigestion are insidious and should be most carefully guarded against.

Coöperation between School and Home

The nursery school child may remain in school till the middle of the afternoon, in which case the interval between the early school dinner and the evening meal may be over five hours. If this is likely to be the case, the school schedule may include a light afternoon feeding, especially for children under three or four. From one half to three quarters of a cup of milk served with a plain hard whole wheat cracker makes a good afternoon refreshment, if it does not interfere with the appetite for supper. Here again adjustment between home and nursery school is imperative. If the appetite for supper is interfered with, the afternoon feeding should be omitted or the size of portions decreased till an adjustment is secured.

If the child has only breakfast and supper at home, the nursery school must be responsible for at least 500 calories. In one nursery school graham crackers are always furnished with the dessert, giving not only extra calories for the children who need them, but also something more to chew.

With the child eating in two places, the best diet cannot be assured unless there is continued coöperation between the

school and the home. By frequent conferences with the parents the dietitian must learn the home situation in detail and they together must arrange a plan which will insure a unified day's dietary for every child. Obviously, this will have to be built around the noonday meal at school, which must serve the whole group with only such modification for individual cases as comes from changes in quantities of food served, since it would be impossible to cook a different meal for each child.

The home breakfast should consist of a well cooked cereal, served with milk, a cup of warm milk to drink, and from one to three slices of toast or zwieback or dry bread. When orange juice is given at the nursery school, not more than one or two tablespoonfuls should be given with the breakfast, and an equal amount of prune or apple pulp may well be substituted. Prunes are valuable where a more laxative diet is needed, and so are cereals made from whole grains.

A very good main dish for supper is a vegetable purée or a creamed vegetable soup with small squares of toasted bread (others are milk toast, or cereal and milk; or sometimes a baked potato with another vegetable cooked soft and well mashed), some bread spread lightly with butter and a cup of warm milk to drink.

There may be added, if the child sleeps well after it, a small serving of mild stewed fruit such as apple sauce, stewed pears, or baked banana. Sometimes a graham cracker or a plain hard molasses cooky will prove less disturbing at night. If a child is very restless at night on such a good régime, it would be advisable to see if increasing vitamin B with some rich concentrate such as wheat germ, wheat germ extract or dextrin or yeast extract will not improve digestion and result in quieter, more restful sleep.

The Kindergarten Child

The child who does not enter a nursery school at the age of two or three years may begin his school experience at the age of four or five in kindergarten. He will have less feeding

A Nursery School Menu for a Week

With suggested breakfasts and suppers [1]

Hour	Monday	Tuesday	Wednesday	Thursday	Friday
Breakfast 250–320 Cal.	Cereal $\frac{1}{3}$–$\frac{1}{2}$ cup Milk 2 oz. Fruit 2–4 tbsp. Toast $\frac{1}{2}$–1 slice Butter $\frac{1}{2}$–1 tsp. Milk 6 oz.	Same	Same	Same	Same
9:15 70 Cal.	Orange juice 3 tbsp. Water 3 tbsp. Karo $\frac{1}{4}$ tbsp. Cod liver oil 1 tsp.	Same	Same	Same	Same
Dinner, 11:30 400–525 Cal.	Pea purée with egg 3–5 tbsp. Mashed potato 3–5 tbsp. Toast $\frac{1}{2}$ slice Butter 1 tsp. Milk $\frac{3}{4}$ cup Apple sauce $\frac{1}{4}$–$\frac{1}{3}$ cup	Scalloped tomatoes 2–4 tbsp. Creamed liver 1–2 tbsp. Baked potato 1 Toast $\frac{1}{2}$–1 slice Butter 1 tsp. Milk $\frac{3}{4}$ cup Fruit cup $\frac{1}{4}$–$\frac{1}{3}$ cup	String beans 2–4 tbsp. Scrambled egg 1 Potatoes 3–5 tbsp. Sandwich 1 slice Milk $\frac{3}{4}$ cup Butter 1 tsp. Orange blanc mange $\frac{1}{4}$–$\frac{1}{3}$ cup	Creamed carrots 3–5 tbsp. Potatoes 3–5 tbsp. Toast $\frac{1}{2}$ slice Milk $\frac{3}{4}$ cup Butter 1 tsp. Tapioca $\frac{1}{4}$–$\frac{1}{3}$ cup	Spinach and egg 3–5 tbsp. Potatoes 3–5 tbsp. Sandwich 1 slice Milk $\frac{3}{4}$ cup Butter 1 tsp. Prune whip $\frac{1}{4}$–$\frac{1}{3}$ cup
2:30 95–175 Cal.	Milk 4–8 oz. Graham crackers 1–2	Same	Same	Same	Same
Supper 310–400 Cal.	Cream of tomato soup $\frac{3}{4}$–1 cup Croutons 1–2 slices Milk $\frac{3}{4}$ cup Baked banana 1	Oatmeal $\frac{1}{3}$–$\frac{1}{2}$ cup Toast 1–2 slices Butter $\frac{1}{2}$–1 tsp. Milk $\frac{3}{4}$ cup Junket $\frac{1}{4}$–$\frac{1}{3}$ cup	Milk toast 2 slices Sandwich $\frac{1}{2}$–1 slice Milk $\frac{3}{4}$ cup Apple sauce $\frac{1}{4}$–$\frac{1}{3}$ cup	Poached egg 1 Toast 1–2 slices Butter $\frac{1}{2}$–1 tsp. Milk $\frac{3}{4}$ cup Fruit cup $\frac{1}{4}$–$\frac{1}{3}$ cup	Cream pea soup $\frac{3}{4}$–1 cup Toast 1–2 slices Butter $\frac{1}{2}$ tsp. Milk $\frac{3}{4}$ cup Rice pudding $\frac{1}{4}$–$\frac{1}{3}$ cup

[1] Rose, M. S., Robb, E., and Borgeson, G. M. "The Food Consumption of Nursery School Children." *Child Development*, Vol. 3, page 29 (1932).

at school than the nursery school child, but there will nevertheless be certain adjustments necessary when he starts on his school career. Breakfast may have to come earlier and dinner later, and a mid-morning school lunch become a practical necessity if he is not to be fagged out before reaching home at midday. The morning hours cannot be spent in the open sunshine, and plans must be made to secure a good sun bath every day that the sun shines. There is danger of hurrying breakfast and eating an insufficient quantity of food, hence the morning program must be arranged to allow for leisurely eating of the proper amount of breakfast and a bowel movement afterward—no mean achievement for a busy mother and a child sure to be slow when any one specially wants him to be quick.

The breakfast should continue to consist of orange juice or other fruit juice (stewed prunes or apple sauce occasionally if preferred), well cooked cereal, toast or other hard bread, and from one to two cups of warm milk, part on the cereal and part to drink. Shredded wheat or zwieback with warm milk poured over it may be now and then used instead of oatmeal or dark farina. In either case the child has a warm wholesome breakfast. For the school lunch, milk as a rule is the most desirable food. The cupful taken then helps to distribute the day's quart advantageously, and the drinking of milk in school tends to reinforce the idea that milk is important. Furthermore, milk is easy to serve and easy to digest. A hard whole wheat or graham cracker will make it digest more quickly. Orange juice has also been used successfully for the mid-morning feeding. It should always be so timed that the interval between it and dinner is longer than the interval between it and breakfast—nearer nine o'clock than ten.

The dinner should come as soon after the school session as practicable and be the most substantial meal of the day. Such dinners as have been outlined for the nursery school children are suitable for kindergartners too.

The evening meal should frequently have as the main dish cereal, toast, or bread with milk, using perhaps rice or some other cereal not served for breakfast. Some of the ready to

eat cereals with plenty of milk are excellent for supper. A creamed vegetable on toast with a strip of bacon may be served as an alternative to the cereal supper or a baked potato with some other vegetable.

A dessert of stewed fruit, junket, or other simple pudding may be supplemented by graham crackers or a plain hard cooky. If the milk is not used for the main dish it should be served as a beverage.

Good distributions for the calories in the young school child's diet are shown below:

Distribution of Calories for Well Balanced Diets of Children from Three to Five Years of Age

Class of Food	Per Cent of Total Calories
I. Foods from cereal grains	18–20
II. Milk, whole	45–55
III. Vegetables and fruits	16–22
IV. Butter	4–8
V. Sugar	1–3
VI. Egg yolk	3–5

For example, an active three-year-old child may need about 1,300 calories per day. A quart of milk will furnish 52 per cent of this total; cereal foods may easily contribute 20 per cent, if we provide 2 slices of bread, $\frac{3}{4}$ cup of cooked cereal, 2 small crackers, and 2 teaspoonfuls of flour to use in making soup. Vegetables and fruits will furnish 17 per cent if we include a potato, two other kinds of vegetable, and two kinds of fruit; an egg will add its quota of 5 per cent, leaving only 5 per cent to come from butter and sugar. The details are given in the following table:

Selection of Food Materials for a Three-Year-Old Child's Diet

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Foods from cereal grains (including bread)	20	2.6	Dark farina (with added wheat germ)	$\frac{3}{4}$ cup, cooked	1.00
			Bread, whole wheat	2 slices	1.00
			Flour	2 tsp.	0.20
			Crackers, whole wheat	2 small	0.40

Class of Food	Per Cent of Total Calories	Calories Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
II. Milk	52	6.8	Milk	1 quart	6.75
III. Vegetables and fruits	17	2.2	Potato	1 medium	1.00
			Carrots (small cubes)	⅓ cup	0.25
			Orange juice	¼ cup	0.25
			Banana	½ medium	0.50
			Beans, green, strained	⅓ cup	0.20
IV. Butter	5	0.7	Butter	2 tsp.	0.65
V. Sugar	1	0.1	Sugar	¾ tsp.	0.15
VI. Eggs and meat	5	0.7	Egg (small)	1	0.65
Totals	100	13.1			13.00

If we desire to see whether our distribution of calories and choice of foods has resulted in a well balanced dietary we may make the following calculations:

A Dietary for a Three-Year-Old Child

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Farina, dark with added wheat germ	¾ cup, cooked	1.00	1.6	0.5	2.5	2.2	—	16.5	—	+
Bread, whole wheat	2 slices	1.00	1.6	0.3	1.4	1.3	—	6.1	—	
Flour	2 tsp.	0.20	0.3	—	0.1	0.1	—	—	—	—
Crackers, whole wheat	2 small	0.40	0.6	0.2	0.8	0.8	—	1.7	—	0.4
Milk, pasteurized	1 quart	6.75	12.8	50.0	20.6	4.7	20.2	10.8	11.7	15.6
Potato, cooked	1 medium	1.00	1.1	0.6	1.5	2.2	0.3	4.8	6.5	1.5
Carrots	⅓ cup cubes	0.25	0.3	1.1	0.5	0.7	17.1	2.8	1.8	1.4
Orange juice	¼ cup	0.25	0.1	0.4	0.1	0.2	0.3	3.9	14.9	0.8
Banana	½ medium	0.50	0.3	0.2	0.4	0.6	1.2	1.5	4.3	0.8
Green beans, strained	⅓ cup	0.20	0.4	1.2	0.6	1.1	4.8	1.6	2.2	0.6
Butter	2 tsp.	0.65	—	0.1	—	—	3.3	—	—	—
Sugar	¾ tsp.	0.15	—	—	—	—	—	—	—	—
Egg	1 egg	0.65	2.3	1.2	2.2	2.5	8.7	2.5	—	3.2
Total		13.00	21.4	55.8	30.7	16.4	55.9	53.2	41.4	24.3
Standard		13.00	16.0	43.0	23.0	15.0	20.0	20.0	40.0	20.0

It will be noted that this selection of common food materials allows a good margin of safety, more than meeting the standards set in several instances. With one or two teaspoonfuls of cod liver oil added for vitamin D, it represents our best present knowledge of how to safeguard the young child. A plan for meals which will use these foods to good advantage is given below:

A Day's Menu for a Three-Year-Old Child

Breakfast: Orange juice, 3 tbsp.
Dark farina, ¾ cup
Milk, 8 oz. (for cereal and to drink)
Toast, whole wheat, 1 slice
Butter, ½ tsp.

Dinner: Potato, mashed, 1 medium
Carrots, steamed and chopped, 5 tbsp.
Toast, whole wheat, 1 slice
Butter, ½ tsp.
Banana, one half in small cubes with ½ tsp. sugar and 1 tbsp. orange juice
Milk, 6 oz.
Cod liver oil, 1 tsp.

2:30 p. m. Milk, 6 oz.
Whole wheat crackers, 2 crackers

Supper: Soft cooked egg, 1 egg
Beans, steamed and chopped, 4 tbsp.
Bread, whole wheat, 1 slice
Butter, 1 tsp.

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CHAPTER XXIV

FOOD NEEDS OF ELEMENTARY AND HIGH SCHOOL BOYS AND GIRLS

How much is a child worth? It has been estimated that a baby born into a family whose total economic resources are $2,500 a year has a potential money value to society of $9,333. This is the amount which it would be necessary to put at interest at 3.5 per cent to rear a child to age eighteen, and to realize finally a sum equivalent to his net earnings during his working years if he earn $2,500 a year. At age five the corresponding figure is $14,156.[1] These estimates are far below the real cost, since no account whatever is taken of the cash value of the mother's services at any period.

No one would consider this large sum of money as indicating the full worth of a child. His presence in health and happiness gives values to life which are immeasurable. But putting a part in terms of hard cash may help us to realize a little better our responsibility for his well-being. The child leaving the kindergarten with an estimated economic worth of $14,000 will pass from the elementary school with this value increased at least 50 per cent provided he is in good health and has learned how to take care of himself. At present the foundation for adult health is not as securely laid as it ought to be, for a study of 500,000 life insurance policyholders reveals that 10,000 of this number must be counted as sick at any given time. Such a reckoning does not take account of the days when these people although at work are miserable and inefficient because of physical disability. Even a cold, which does not prevent most people from carrying

[1] Dublin, L. I. "The Economics of World Health." *Harper's Magazine*, Vol. 153, page 734 (1926).

through the day's routine, may change entirely the quality of work done.

By more attention to the health of the pre-school and kindergarten child, we can cut down many of the handicaps which today are found among elementary school children. Physical defects should have been as far as possible removed and good health habits already established when the six-year-old enters the primary school. But he cannot now be safely left to guide himself. He has covered only about one fourth of his period of growth, and good habits are by no means fixed. Furthermore, he is just approaching the years in which inculcation of the reasons for health habits and respect for the laws of hygiene should be a consistent part of his education, both at home and at school. "We strike at one of the roots of physical unfitness when we begin the teaching of food selection to all children, regardless of whether they appear to be undernourished or not. No immediate striking gain in weight is the objective of such teaching. What we want is to rear children who are intelligent as to the rôle which food plays in their lives, who are aware of their own responsibility in regard to food selection, and are imbued with a determination to make their daily food a factor contributing to health and not working against it, even though results cannot be measured from day to day nor from week to week—only from month to month or year to year. To this end they must have, (1) the habit of eating certain foods which in large measure insure a well balanced diet, (2) sufficient knowledge of the part played by individual foods to make up for themselves suitable combination for meals, (3) such knowledge of their own food requirements as will enable them to satisfy their needs at a table provided for persons with varying requirements, (4) such ideas of the relation of nutritive value to cost of food as will enable them to be thrifty in meeting their body needs." [1]

[1] *Health Education Report of the Joint Committee on Health Problems in Education*, page 52 (1930). For suggestions for teaching nutrition to children see Rose, M. S. *Teaching Nutrition to Boys and Girls.* The Macmillan Co. (1932).

Section I

ELEMENTARY SCHOOL CHILDREN

By the time a child is ready to enter the elementary school he should be eating a dietary in which milk, eggs, cereals, simply cooked vegetables in considerable variety, mildly acid fruits, mostly stewed save for orange juice, hard dry bread and butter are the chief items in the diet. All foods should be cooked as simply as possible. A glass of milk at each meal and a cup used in soup or dessert will generally take care of the daily quart satisfactorily. No tea or coffee should be permitted, nor even strong cocoa. A very little cocoa may be used to flavor warm milk, but often a little malted milk or a powdered cereal beverage will serve for flavor quite as well.

Raw vegetables should be grated or finely cut and used in small quantities until the habit of thoroughly chewing them is established. They should be seasoned with a little mild fruit juice, not with the salad dressings commonly used by adults. Fat is best used as a spread for bread, rather than in cooking. Whole milk is better to use over cereals and puddings than cream. No soft cake should be permitted, but one or two graham crackers or plain hard cookies may be used at the end of a meal.

Training Children to Eat

Regularity and simplicity are the great watchwords for the diet of the elementary school child. More and more he will take an interest in his own food, and more and more opportunity will come to teach respect for all good food because of what it can accomplish for the body. Talk about personal likes and dislikes should be discouraged. The idea that one can get over distaste for food which one knows to be wholesome by repeated efforts to eat small portions should be substituted for any discussion of dislikes. Minor changes in the food often help the child in such an endeavor. A little

difference in appearance, flavor, or texture may mean more than an adult is aware of. Grownups make many such adjustments for themselves at the table. Why do pepper and salt shakers appear there, save for this very purpose? "Some like it hot, some like it cold," and which way they have it may be immaterial. It is a wise parent that knows when to insist! Spinach and potato together may be easier to eat than spinach alone. A little more salt or a few grains of brown sugar may make the oatmeal seem like a different food. Remember Dickens's kitten pies—whatever the kind of meat, "it's flavorin' as does it!" Fair substitutes may often be allowed when they do not work injustice to any one else. If a child prefers shredded wheat to oatmeal may he not have it, since no work is involved in preparing it and the two foods are nutritionally interchangeable? Eventually, he should learn to eat both, but tastes and ideas change and if he is eating according to his own nutritional needs we should not at this time put too much emphasis on variety.

Any one responsible for feeding a child should be familiar with some of the striking effects of food upon health and growth such as have been referred to in the preceding chapters, and these should be used to put the choice of food upon a higher plane than mere fancy. The demonstration of the effect of food upon the growth and health of animal pets gives a real incentive to eat what one needs regardless of whether it seems most attractive at the moment, and no attitude is more valuable for future health.

In order to fit properly into the family routine every child should be expected to taste any food which it is important for him to eat, every time it is served, but the quantity insisted upon should not be too large if it is difficult for him to take. Frequent repetition under favorable circumstances is much more likely to be successful than a forced overdose. Other habits are established only by patient repetition, and one should not expect food habits to be any exception. Desirable attitudes toward food may be cultivated by taking pains to prepare the child's mind in advance for any new food

he is to have, instead of springing it upon him without any recommendation or at an unfavorable moment.

General Plan of Meals

The primary school child's energy needs are high but his digestive tract still needs to be carefully safeguarded. Breakfast must be ample, but very simple and not eaten too hurriedly. No child starts the day well who has not gone to bed early (before 7:30 P. M.) and had a full night's sleep. During the night he needs fresh cool air to give him a good appetite for breakfast. Fruit, a warm cereal with milk, milk to drink (not chilled) and toast to chew, make a breakfast adequate as to food value and easy to digest. The warm cereal dish may consist of a cooked cereal with cold milk, or a ready to eat cereal with warm milk. Care must be taken to have breakfast at the regular time on Saturdays and Sundays as well as school days, and also meals of the same general character. Every day is growing day for a child and whatever food program is important today is equally important tomorrow. By the age of six or seven, orange juice may give place to the whole orange, prune pulp to whole stewed prunes, and apple sauce to raw apples or pears provided they are perfectly ripe. Other mild fresh fruits can also be used for breakfast in their season.

School conditions will now affect the time and character of the midday meal. In the rural district it will be eaten at the school. There should always be one hot dish available, since warm food promotes the circulation, relieves fatigue, and makes the afternoon session easier. Cocoa made with milk or a nutritious milk and vegetable soup with bread and butter (or sandwich) and fruit will make a wholesome noonday meal. When the children can go home for dinner, a potato, another cooked vegetable, an egg, or a little meat, a small portion of some raw vegetable such as lettuce, tomatoes, cabbage, or carrots, a glass of milk to drink, and a simple dessert of stewed fruit or a milk pudding make a suitable meal. All the foods should be simply cooked, for the child

must go back to school to use his brain, and a meal difficult to digest must not take all the blood away from his head. The delicate child will benefit from a short rest flat on his back before his dinner; the very active one who wants to eat and run to his play should be kept at the table for at least twenty or thirty minutes so that he will not be tempted to bolt his food.

The evening meal must be simple, since bedtime is not far away. A creamed vegetable soup with toast or crackers, a cooked vegetable and bacon on toast, a soft cooked egg with a baked potato, milk toast, cereal and milk are examples of suitable hot dishes. There should be milk to drink, bread and butter with stewed fruit, or a simple pudding for dessert.

As other foods are built into the diet around the quart of milk which forms its broad and sure foundation, the proportion of the total calories coming from the milk will naturally be less, but will never be an insignificant part of the whole. Good distribution of calories for children six to twelve years of age will usually have more than one third and less than one half of the calories contributed by milk.

Distribution of Calories for Well Balanced Diets of Elementary School Children

Class of Food	Per Cent of Total Calories for Different Ages			
	6–7 Years	8–9 Years	10–12 Years	Range
I. Food from cereal grains	22	21	20	20–25
II. Milk	45	40	34	34–45
III. Vegetables and fruits	16	18	20	16–20
IV. Butter	10	12	14	10–15
V. Sugar	3	4	6	3–6
VI. Eggs, cheese, meat, and other flesh foods	4	5	8	4–8

To illustrate the selection of food for a child within this age range, we may plan a dietary for a nine-year-old boy, requiring 2,000 calories per day, allotting 22 per cent of the total calories to cereal foods, 34 per cent to milk, 17 per cent to vegetables and fruits, 13 per cent to butter, 6 per cent to

sugar, and 8 per cent to eggs and meat. A good selection of foods is indicated in the following table:

Selection of Food Materials for a Nine-Year-Old Boy's Diet Requiring 2,000 Calories

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Food from cereal grains (including bread)	22	4.4	Dark farina (cooked)	½ cup	0.60
			Bread, whole wheat	2 slices	1.60
			Bread, white	2 slices	1.25
			Graham crackers	2 large	0.80
			Flour	½ tbsp.	0.15
II. Milk	34	6.8	Milk	1 quart	6.75
III. Vegetables and fruits	17	3.4	Potatoes	2 small	1.40
			Carrots	1 small	0.20
			Lettuce	3 leaves	0.05
			Peas	⅓ cup	0.45
			Orange	1 medium	0.80
			Apple	1 small	0.50
IV. Butter	13	2.6	Butter	2½ tbsp.	2.60
V. Sugar	6	1.2	Sugar	2+ tbsp.	1.20
VI. Eggs, cheese, meat, etc.	8	1.6	Hamburg steak	¼ cup	0.90
			Egg	1 egg	0.70
Total	100	20.0			19.95

How this plan will meet the needs of the boy is shown by the calculations on the following page.

It is now easy to see that requirements for protein and mineral constituents are well met when the calories are selected with regard to their ability to furnish these other essentials, too. It is also easy to see how difficult it would be to meet the calcium and phosphorus needs of a rapidly growing boy without a liberal amount of milk, since the contributions of the other foods are so insignificant in comparison.

The dietary furnishes nearly 64 shares of vitamin A of which milk supplies nearly one third and carrots nearly one fourth, and the egg and butter together another one third. This would appear ample to meet the needs of growth at this age, but since the dietary may not always include vege-

tables as rich in this vitamin as carrots, the addition of a small amount of cod liver oil to insure plenty of vitamin D may be regarded as also valuable to increase the body reserves of vitamin A.

A Dietary for a Nine-Year-Old Boy

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Farina, dark, cooked	½ cup	0.60	0.7	0.3	1.6	1.7	—	2.5	—	0.7
Bread, whole wheat	2 slices	1.60	2.5	1.4	2.2	2.1	—	9.8	—	+
Bread, white	2 slices	1.25	1.8	0.6	1.0	0.9	—		—	—
Crackers, graham	2 large	0.80	0.8	0.2	0.9	0.7			—	
Flour	½ tbsp.	0.15	0.2	—	0.1	0.1	—	—	—	—
Milk, pasteurized	1 quart	6.75	12.8	50.0	20.6	4.7	20.2	10.7	11.7	15.6
Potatoes, cooked	2 small	1.40	1.5	0.8	2.1	3.1	0.4	6.7	9.1	2.1
Carrots, cooked	1 small	0.20	0.2	0.9	0.4	0.5	13.7	2.2	1.0	1.1
Lettuce, bleached	3 leaves	0.05	0.1	0.2	0.3	0.3	0.4	1.0	0.9	0.4
Peas, cooked	⅓ cup	0.45	1.3	0.5	1.3	1.8	4.5	10.1	8.1	2.3
Orange	1 medium	0.80	0.6	1.8	0.7	1.7	1.0	11.6	47.2	2.5
Apple	1 small	0.50	0.1	0.3	0.2	0.6	0.6	2.0	4.0	0.8
Butter	2½ tbsp.	2.60	0.1	0.2	0.1	0.2	13.3	—	—	—
Sugar	2+tbsp.	1.20	—	—	—	—	—	—	—	—
Hamburg steak, cooked	¼ cup	0.90	4.9	0.3	2.7	3.4	0.4	2.2	—	2.9
Egg	1 egg	0.70	2.5	1.3	2.4	2.7	9.4	2.7	—	3.4
Total		19.95	30.2	58.8	36.6	24.5	63.9	61.5	82.0	31.8
Standard		20.00	24.0	43.0	20.0	20.0	20.0	20.0	40.0	20.0

The choice of dark cereals and a vegetable (peas) known to be more than usually rich in vitamin B to supplement the milk and the orange results in a total of more than 60 shares, which should be ample even for an active child of this age. The value of milk for vitamin G is better appreciated by seeing that it furnishes fully half of the total amount in the diet. The value of the orange as a source of vitamin C is quite apparent, as it provides more than half of the

total number of shares, and would meet the standard set without taking account of any other food. The regular use of specific foods for special purposes as in this instance, greatly simplifies the task of providing adequate diets.

Section 2

HIGH SCHOOL BOYS AND GIRLS

By the time a boy or girl is twelve years old, the upper elementary or junior high school will usually have been reached, and the period of adolescence will have begun. In this period, lasting about ten years, there is a gradual transition from childhood to maturity. Growth, which has been proceeding with a weight increase averaging between 5 and 6 pounds a year is accelerated about the twelfth year in girls and the thirteenth in boys, as indicated by the following tables:

Rate of Growth for Boys of School Age

Age—Year		6	7	8	9	10	11	12	13	14	15	16	17	18	19
Average height (inches)	Short	43	45	47	49	51	53	54	56	58	60	62	64	65	65
	Medium	46	48	50	52	54	56	58	60	63	65	67	68	69	69
	Tall	49	51	53	55	57	59	61	64	67	70	72	72	73	73
Average annual gain in weight (lbs.)	Short	3	4	5	5	5	4	8	9	11	14	13	7	3	—
	Medium	4	5	6	6	6	7	9	11	15	11	8	4	3	—
	Tall	5	7	7	7	7	8	12	16	11	9	7	3	4	—

Rate of Growth for Girls of School Age

Age—Year		6	7	8	9	10	11	12	13	14	15	16	17	18
Average height (inches)	Short	43	45	47	49	50	52	54	57	59	60	61	61	61
	Medium	45	47	50	52	54	56	58	60	62	63	64	64	64
	Tall	47	50	53	55	57	59	62	64	66	66	67	67	67
Average annual gain in weight (lbs.)	Short	4	4	4	5	6	6	10	13	10	7	2	1	—
	Medium	5	5	6	7	8	10	13	10	6	4	3	1	—
	Tall	6	8	8	9	11	13	9	8	4	4	1	1	—

In most of the years between 6 and 17 the average growth in height of boys and girls is about 2 inches and in the years of greatest growth about 3 inches, though some boys grow 4 or 5 inches in the year of greatest growth. Just preceding the period of accelerated growth, the basal metabolism

resembles that of the previous year or two, being relatively high for girls at the ages of 12 and 13, and for boys from 12 to 14; when puberty is established the metabolism falls

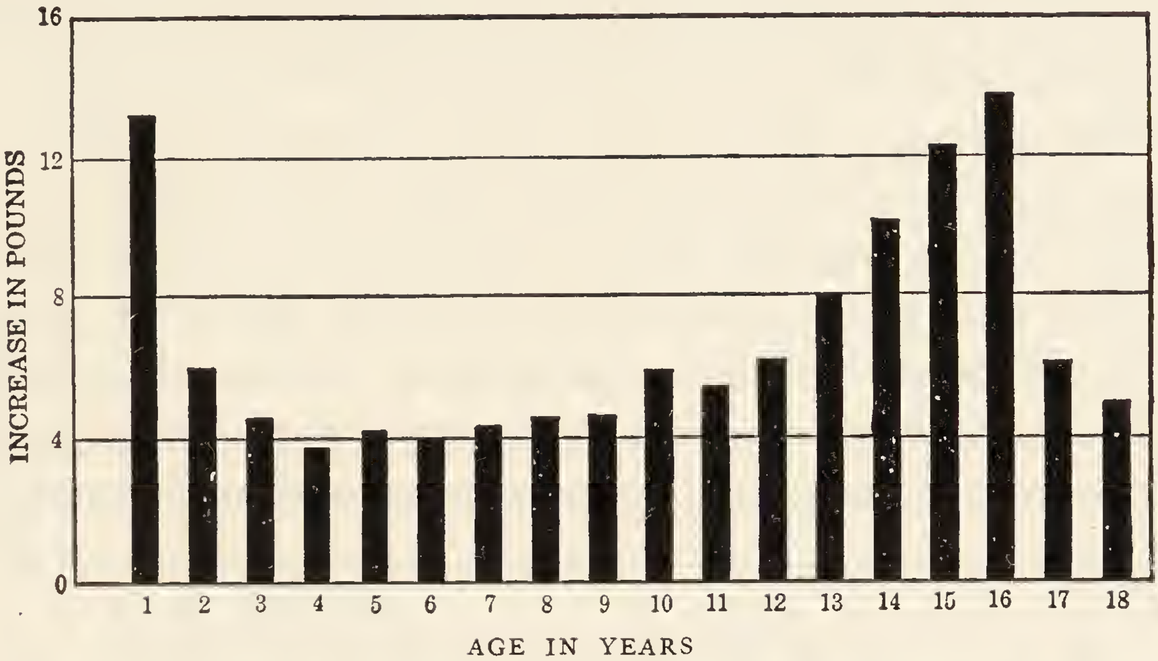

FIG. 113.—Increase in Weight of Boys from Birth to the Eighteenth Year.

rather sharply, as has already been shown in Chapter V. For the whole period from 12 to 16 years in girls and 12 to 18 years in boys, the food requirements will be much

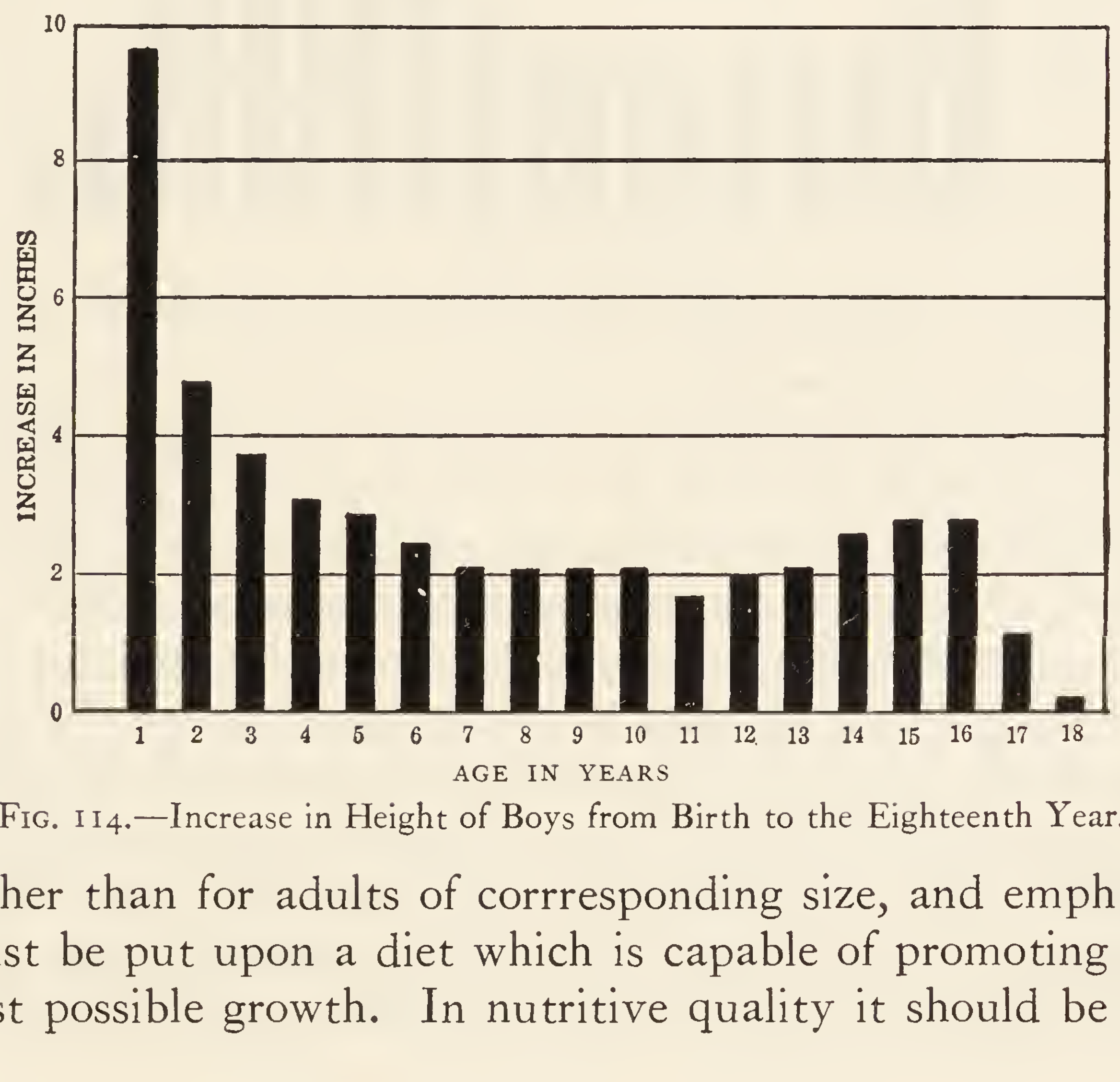

FIG. 114.—Increase in Height of Boys from Birth to the Eighteenth Year.

higher than for adults of corrresponding size, and emphasis must be put upon a diet which is capable of promoting the best possible growth. In nutritive quality it should be the

equal of that for the younger children, and in quantity it will resemble the diets of toilers, such as farm laborers and stone workers.

It is important that regularity of meals and the habit of eating plain wholesome food be maintained throughout the growing period. The one who faces a food requirement of from 1,000 to 1,500 calories per meal has occasion to give thought to the concentration of the diet, in order to insure a sufficiency without undue strain upon the digestive tract on the one hand or "meals at all hours." In *Seventeen*, Booth Tarkington has well depicted the tendency of the voracious age, in Jane, who is continually eating bread and apple sauce and

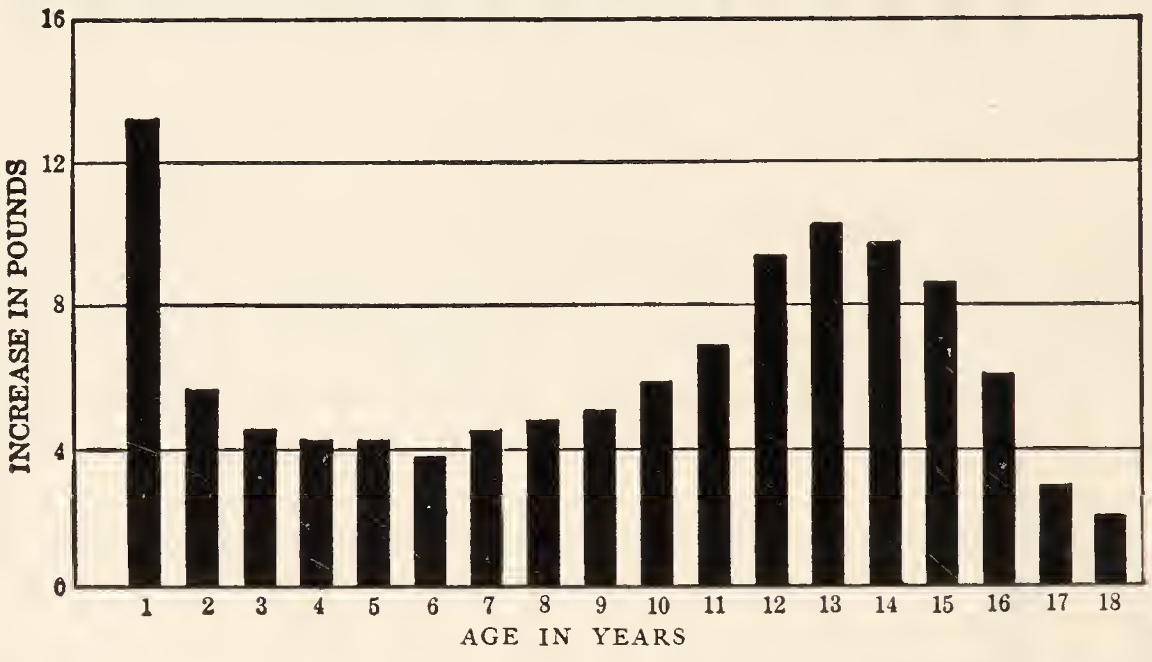

FIG. 115.—Increase in Weight of Girls from Birth to the Eighteenth Year.

brown sugar. That is not the best way, however, to meet the high food needs of adolescence. With care, the needed calories can be given for the most part in three regular meals, though opportunity to secure a little extra nourishment in the form of bread and butter, or crackers and milk, is often necessary.

A quart of milk a day should be allowed for each boy and girl, and if this is all taken as a beverage more may be used in cooking. The use of foods from the cereal grains should be encouraged; various forms of bread are most useful, especially those of whole grains reinforced with nuts, dates, raisins, etc. Sweet dried fruits (dates, raisins, and figs) with their high fuel and ash values admirably supplement fresh

fruits, and can be used in many ways. That an excellent luncheon can be prepared of figs, peanuts, and bread and butter has already been shown on page 426. Vegetables whose fuel value is low can be cooked with more butter or

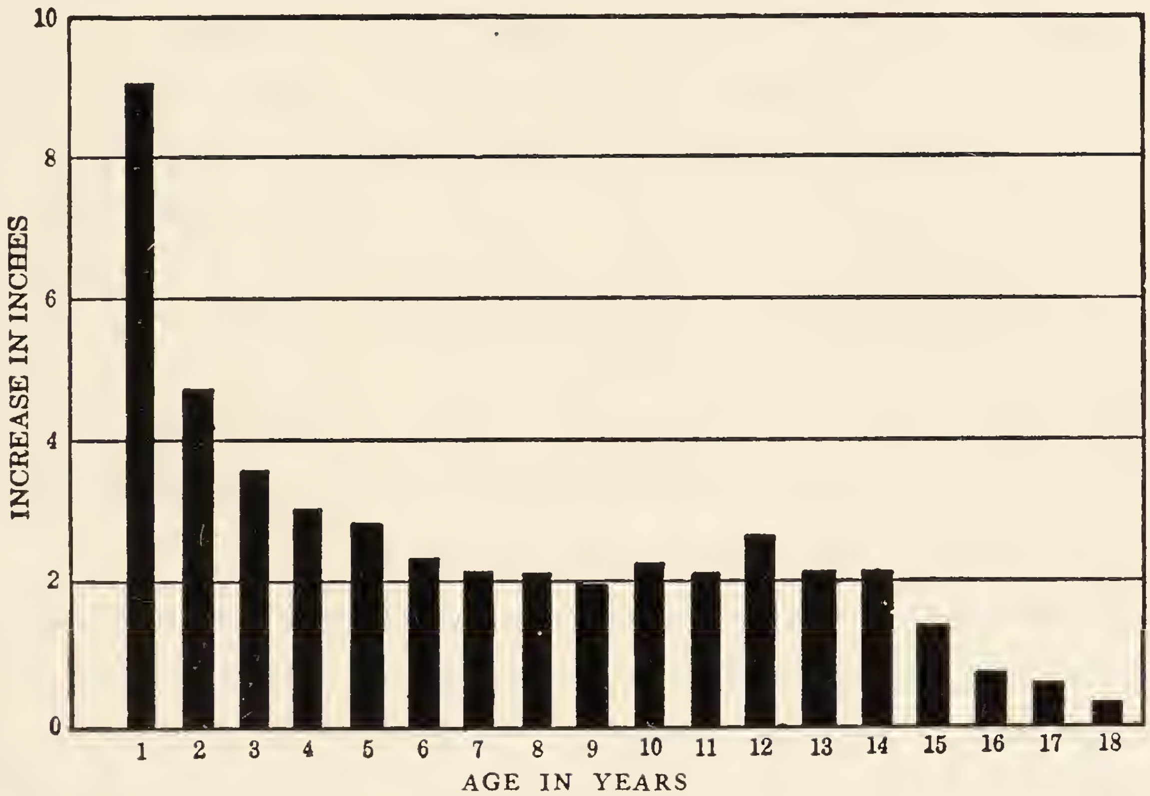

Fig. 116.—Increase in Height of Girls from Birth to the Eighteenth Year.

with white sauce, and salads can now have the cream or oil dressings which add so many calories in a small volume, provided they are not highly seasoned. Meat, while not a necessity, is an acceptable addition to the diet by reason of its appetizing properties and its power of giving the "staying" qualities which are such a desideratum at this age. It should be borne in mind that meat needs supplementing always by milk and vegetables, to give the calcium and vitamins which it lacks. It is interesting to see how meat, which has little calcium or vitamins, can be supplemented by milk and potato to make a better balanced ration.

How Milk and Potato Supplement Meat

Food Material	Measure	Shares								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Beef, med. fat	4 ounces	2.7	8.0	0.5	5.0	4.6	0.7	3.4	—	4.8
Milk	1 cup	1.7	3.2	12.5	5.2	1.2	5.1	2.7	2.9	3.9
Potato	2 medium	2.0	2.2	1.2	3.0	4.4	0.6	9.6	13.0	3.0
Total		6.4	13.4	14.2	13.2	10.2	6.4	15.8	15.9	11.7

Some Considerations Influencing Choice of Food

The kinds of food habits which boys and girls form as they come to make their own choices are the food habits they tend to carry over into adult life. A taste for plain, wholesome food, simply prepared, is a most valuable nutritional safeguard, and should be fostered in every possible way. If the appetite is not "up to" milk, vegetables, and fruits well cooked, and served accompanied by good bread and butter, something is wrong with the mode of life and the remedy is not highly seasoned food, such as "hot dogs," pickles, mince pie, or ice cream soda. Often what is most needed is more sleep, less excitement, and fewer temptations to make eating "the great indoor sport."

Boys are more likely than girls to accept without protest a simple régime provided it really gives them a diet which appeases their chronic hunger. Quantity is the great consideration. Girls, whose urge to eat is not so compelling, pay more attention to the esthetic aspects of their diet. This is somewhat true even of girls leading active lives and taking their recreation in the form of outdoor sports. It will cost just as much to feed a girl as a boy although she eats a third less calories, because the calories she does eat must carry nearly as much building and regulatory material as his, and her normal food intake is less sustained by the demand of hunger and more through the appeal which the food makes to the eye. Many of the dietary problems presented by girls can be met ideally only as physical perfection can be made to seem worth working for. Not yet do women as a class take pride in physical fitness; on the contrary many, even today, take offense at any suggestion that they are perfectly well and begin to parade their disabilities. A girl must see advantages in health in order to be willing to strive for it. Where thinness is admired she will work for thinness; where fatness is regarded as a mark of beauty, she will do her best to be fat. Her desire for beauty and praise far outruns her desire for food, and it will only be as

higher ideals are developed that she will consciously endeavor to live hygienically. Her diet should be chosen with regard to its appearance and flavor, with emphasis upon growth promoting factors. Plenty of fruit and vegetables, eggs, and nuts, along with a quart of milk a day, may well constitute a large part of the dietary at this time. Cakes, pies, fancy desserts, and candy cut down the proportion of ash and vitamins and are likely to disturb digestion. For the sake of good teeth and hair and a clear complexion they should be ruled out as far as possible. There is no better habit than that of persistently choosing simply prepared foods of delicate flavor. Any tendency to highly flavored foods, whether sweets, pickles, pepper, catsup, or other so called food adjuncts, every one should learn to curb in himself, not because of any immediate harm but because wise food habits acquired and maintained are the surest and easiest road to good nutrition so far as choice of food is a factor, while the habit of demanding highly seasoned food is bound to grow, and make the more wholesome plain foods distasteful.

The best regulator of appetite is plenty of fresh air and sunshine, with long hours of sleep at night. Regular meals should be insisted upon, even if little food be eaten and if a girl is underweight, more rest should be taken to cut down energy expenditure and make it balance food intake.

Since adolescent boys have a greater need of fuel foods than adolescent girls, the distribution of the typical food groups will vary with the total number of calories required. The table on page 498 suggests distributions suitable for different levels of energy intake for high school boys and girls.

The test of any such plan is the nutritive value of a dietary based upon it. In the two which follow, one worked out in detail for a boy requiring 5,000 calories per day and the other for a girl requiring 2,500, we have evidence that there has been adequate provision of building materials as well as calories, and we have every reason to believe that the vitamin supply is ample. Nevertheless, during this period of rapid growth, the inclusion of a daily portion of cod liver

Distribution of Calories for Adequate Diets of High School Boys and Girls

Class of Food	Percentage of Total Calories Required per Day			
	Boys			Girls
	5,000 Calories	4,000 Calories	3,000 Calories	2,300–2,800 Calories
I. Food from cereal grains (including bread)	27	26	22	18
II. Milk	15	18	24	25
III. Vegetables and fruits	18	18	18	20
IV. Fats	18	18	18	18
V. Sugars	10	10	10	10
VI. Eggs, cheese, meat, etc.	12	10	8	9

oil in the winter season may be regarded as an additional safeguard, not only because it furnishes vitamin D, but because it also adds to the reserves of vitamin A for the boy's

Selection of Food Materials for a Boy Requiring 5,000 Calories

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Food from cereal grains (including bread)	27	13.5	White rolls	2 rolls	2.0
			Whole wheat bread	6 slices	3.0
			Graham crackers	8 crackers	2.0
			Oatmeal (cooked)	$2\frac{1}{4}$ cups	3.0
			Flour, white	$\frac{4}{5}$ cup	3.5
II. Milk	15	7.5	Milk	38 ounces	7.5
III. Vegetables and fruits	18	9.0	Potatoes	3 medium	3.2
			Cabbage (shredded)	1 cup	0.3
			Peas	$\frac{3}{4}$ cup	1.0
			Dates	8 dates	2.0
			Apples	2 medium	1.5
			Lettuce	$\frac{1}{2}$ head	0.3
			String beans	$1\frac{1}{2}$ cups	0.7
IV. Fats	18	9.0	Butter	5 tbsp.	5.0
			Bacon (raw)	1 ounce	2.0
			Drippings	2 tbsp.	2.0
V. Sugars	10	5.0	Sugar, granulated	6 tbsp.	3.0
			Molasses	3 tbsp.	2.0
VI. Eggs, cheese, meat, etc.	12	6.0	Beef, medium fat	5 ounces	3.5
			Eggs	3 eggs	2.5

diet shown below. The food materials are chosen, first, with reference to the total calories, so that each group may be adequately represented; and second, within the groups, to make each group carry ash constituents and vitamins. Part of the cereal group is from foods in which the bran and germ

A Day's Dietary for a Boy Requiring 5,000 Calories

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Rolls, white	2 rolls	2.0	2.8	1.0	1.6	1.4	—	+	—	—
Bread, whole wheat	6 slices	3.0	4.7	1.0	4.2	3.9	—	18.3	—	+
Crackers, graham	8 large	2.0	1.9	0.4	2.2	1.8		—		
Oatmeal, cooked	2¼ cups	3.0	5.0	2.2	6.6	7.2	—	10.5	—	+
Flour, white	⅘ cup	3.5	4.5	0.6	2.4	2.0	—	0.4	—	—
Milk, pasteurized	4¼ cups	7.5	14.3	55.5	22.9	5.3	22.6	12.0	13.1	17.4
Potatoes, cooked	3 medium	3.2	3.4	1.9	4.7	7.1	1.0	15.4	20.8	4.8
Cabbage, raw	1 cup shredded	0.3	0.6	1.9	0.7	0.8	0.6	4.8	25.3	2.4
Peas, cooked	¾ cup	1.0	2.8	1.0	2.9	4.0	10.0	22.5	18.0	5.0
Dates	8 dates	2.0	0.5	1.7	0.7	4.2	0.6	2.4	—	
Apples, cooked	2 medium	1.5	0.4	0.9	0.6	1.6	1.8	6.0	1.2	2.4
Lettuce	½ head	0.3	0.8	1.3	1.6	1.8	2.2	6.5	6.0	2.2
String beans, cooked	1½ cups	0.7	1.5	4.1	2.0	3.9	16.9	5.6	7.7	2.1
Butter	5 tbsp.	5.0	0.3	0.4	0.3	0.3	25.5	—	—	—
Bacon, raw	1 oz.	2.0	1.4	0.1	0.7	0.8	+	—	—	+
Drippings	2 tbsp.	2.0	—	—	—	—	—	—	—	—
Sugar, granulated	6 tbsp.	3.0	—	—	—	—	—	—	—	—
Molasses	3 tbsp.	2.0	0.7	7.8	0.4	10.2	—	—	—	—
Beef, medium fat, cooked	5 oz. raw wt.	3.5	10.2	0.7	6.8	5.9	0.8	4.2	—	6.0
Eggs	3 eggs	2.5	9.1	4.5	8.6	9.8	33.5	9.8	—	12.3
Total		50.0	64.9	87.0	69.9	72.0	115.5	118.4	92.1	54.6
Standard		50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0

are retained; the fruit and vegetable group contains peas and string beans, rich in vitamin A; the fats include butter with its vitamin A; the sugars, molasses with a considerable amount of needed iron; and the meat group, eggs, rich in various kinds of building materials and vitamins, but es-

pecially valuable for vitamins A and G and for phosphorus and iron, and the meat, which gives a considerable number of calories because of its fat, and also contributes a significant amount of protein, phosphorus, and vitamin G.

The fruits, apples, and dates, are usually available in winter, when other kinds may not be plentiful and money must be spent for foods furnishing as many calories as possible. Another fruit, equally desirable, would be the banana, with as many calories as apples and more vitamins, especially vitamin A.

The calculations show how milk, which has become a less prominent source of calories, is still the mainstay for calcium and phosphorus. The dietary yields a liberal amount of iron, over one half of which comes from the cereal grains and fruits and vegetables, and over one fourth from the eggs and molasses. There are 116 shares of vitamin A, very valuable at a time of rapid development of all parts of the body, nearly three fourths of which are contributed by milk, butter, and eggs, the rest mainly from the vegetables. Vitamin B is also liberally provided, to meet the extra demands of great activity as well as rapid growth. The whole wheat bread and oatmeal furnish one fourth of the total amount, peas alone about one fifth, and milk and potatoes together a little more than one fourth. The total amount is twice the standard which allows a wide margin of safety for growth. In this dietary cabbage, potatoes, and peas contribute two thirds of the vitamin C and insure adequacy in respect to this vitamin. As this is probably several times the minimum necessary to prevent scurvy, it should afford good tooth protection, but for further safety, some food richer in vitamin C, as oranges or tomatoes, ought to be used frequently. One third of the vitamin G is furnished by milk and this is well supplemented by the eggs and meat, which together furnish another third. Provision for vitamin D must be made by much outdoor exposure to the sun in summer, and by some special source, as cod liver oil or its equivalent in winter.

A simple, wholesome menu, showing how these foods may be distributed among three meals, is shown below:

Menu

Breakfast	*Luncheon*	*Dinner*
Dates	Hash (meat and potato)	Meat with gravy
Oatmeal	Peas	Potatoes
Milk	Cabbage (slaw)	String beans
Toast	Whole wheat bread and butter	Lettuce
Bacon	Gingerbread	Rolls and butter
Eggs	Milk to drink	Apple Betty with milk and sugar
Milk to drink		Graham crackers
		Milk to drink

The problem of feeding a high school girl is quite unlike that of providing for a boy of the same age. In the first place, the difference in energy needs is usually quite marked. The basal metabolism of girls comes down rapidly toward the adult level about the thirteenth year (cf. table, page 90) while that of boys remains high; hence a girl may require less than 35 calories per kilogram per day whereas a boy is likely to need at least 40. Furthermore, the activities of high school girls tend to be of a less strenuous type than those of boys, and for shorter periods of time. Consequently, a girl may need a total of 2,500 calories per day at the age when a boy would eat 4,000 calories or even more.

In spite of a lower calorie requirement, the growing girl needs a very liberal supply of minerals and vitamins. She is not so much interested in the foods mainly valuable for their calories, such as breakfast foods and bread, and the percentage of total calories from the cereal group may well be reduced to less than 20 per cent, but milk should still be used freely to maintain a high intake of calcium and phosphorus and of vitamins A, B, and G. Fruits and vegetables should be kept as high as finances permit, preferably not less than 20 per cent of the total calories. Girls' desire for food being less urgent, and sweet food making a strong appeal, the liberal use of fruits is to be encouraged. Salads twice a day are desirable for her, too, and the daily inclusion

Selection of Food Materials for a Girl Requiring 2,500 Calories

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Calorie Shares
I. Food from cereal grains (including bread)	17	4.2	Rolls, white	2 rolls	1.0
			Bread, rye	2 slices	1.0
			Wheat, shredded	1 biscuit	1.0
			Flour, white	5 tbsp.	1.2
II. Milk	25	6.3	Milk	32 ounces	6.3
III. Vegetables and fruits	20	5.0	Orange	1 medium	0.8
			Apple	1 medium	0.8
			Banana	1 medium	1.0
			Potato	1 large	1.5
			Lettuce	$\frac{2}{5}$ head	0.2
			Celery	$3\frac{1}{2}$ ounces	0.2
			String beans	$\frac{1}{2}$ cup	0.3
			Raisins	5 raisins	0.2
IV. Fats	18	4.5	Butter	3 tbsp.	3.0
			Other fat	$1\frac{1}{2}$ tbsp.	1.5
V. Sugars	10	2.5	Sugar, granulated	3 tbsp.	1.5
			Molasses	$1\frac{1}{2}$ tbsp.	1.0
VI. Eggs, cheese, meat, etc.	10	2.5	Beef, lean	4 ounces	1.8
			Egg	1 egg	0.7

of an egg is another excellent safeguard. The preceding table shows how foods may be selected to meet the needs of a girl requiring 2,500 calories per day.

Note in the dietary on page 503 that the milk alone supplies more than the standard allowance for calcium, while all the vegetables and fruits together furnish only one fourth as much as the milk; and also that they supplement the milk as to iron, yielding fully one third of the total iron in the diet.

Even though the butter is quite liberally provided in this diet in which the total calories were to be kept moderate, milk still remains the most prominent source of vitamin A. Here again, milk, butter, and egg provide nearly three fourths of the total vitamin A. This diet has about as many vitamin B units per 100 calories as the boy's diet yielding 5,000 calories, and since the girl is less active and growing (probably) less rapidly, they are likely to be sufficient. It will be noted that the lowering of the allowance of whole grain

A Day's Dietary for a Girl Requiring 2,500 Calories

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Rolls, white	2 rolls	1.0	1.4	0.5	0.8	0.7	—		—	—
Bread, rye	2 slices	1.0	1.4	0.4	1.3	1.3	—	4.4	—	
Shredded wheat	1 biscuit	1.0	1.3	0.5	2.0	2.5	—	2.8	—	
Flour, white	5 tbsp.	1.2	1.6	0.2	0.8	0.7	—	—	—	—
Milk, pasteurized	$3\frac{7}{8}$ cups	6.3	11.9	46.4	19.1	4.4	18.8	10.1	10.7	14.6
Orange	1 medium	0.8	0.6	1.8	0.7	1.7	1.0	11.6	47.2	2.5
Apple, raw	1 medium	0.8	0.2	0.5	0.3	0.9	1.0	3.2	6.4	1.3
Banana, raw	1 medium	1.0	0.5	0.4	0.7	1.3	2.4	2.9	8.5	1.5
Potato	1 large	1.5	1.6	0.9	2.2	3.3	0.5	7.2	9.8	2.3
Lettuce	$\frac{3}{5}$ head	0.2	0.5	0.9	1.1	1.2	1.4	4.4	5.0	1.4
Celery	$3\frac{1}{2}$ oz.	0.2	0.5	3.4	1.1	1.2	0.1	+	5.0	
String beans, cooked	$\frac{1}{2}$ cup	0.3	0.7	1.7	0.9	1.7	7.2	2.4	3.3	0.9
Raisins	5 raisins	0.2	—	0.2	0.2	0.3	—	0.3	—	0.1
Butter	3 tbsp.	3.0	0.2	0.3	0.2	0.2	15.3	—	—	—
Other fat	$1\frac{1}{2}$ tbsp.	1.5	—	—	—	—	—	—	—	—
Sugar, granulated	3 tbsp.	1.5	—	—	—	—	—	—	—	—
Molasses	$1\frac{1}{2}$ tbsp.	1.0	0.3	3.9	0.2	5.1	—	—	—	—
Beef, lean, cooked	4 oz. raw wt.	1.8	9.9	0.7	5.4	6.8	0.7	4.4	—	5.8
Egg	1 egg	0.7	2.5	1.3	2.4	2.7	9.4	2.7	—	3.4
Total		25.0	35.1	64.0	39.4	36.0	58.4	56.4	95.9	33.8
Standard		25.0	25.0	43.0	25.0	25.0	25.0	25.0	30.0	25.0

cereals and substituting string beans for peas cut down the total supply of vitamin B, and it would be a good plan to add some wheat germ to the shredded wheat, or even to substitute wheat germ for it entirely in order to give the girl at this critical age a generous supply of this vitamin so essential to good appetite and digestion.

Daily use of an orange will cover actual requirement for vitamin C and yet the additional sources may be regarded as good health insurance, keeping the tissues well saturated.

Vitamin D must be provided for in some regular way, and cod liver oil is excellent for the purpose or milk enriched with vitamin D may be a convenient source. A menu showing how these foods may be combined in simple but attractive meals, is shown on the following page:

MENU

Breakfast	*Luncheon*	*Dinner*
Orange	Apple and celery salad	Meat
Shredded wheat	Rye bread and butter	Potato
Milk to drink	Molasses and raisin drop cake	String beans
Toasted roll and butter	Cocoa	Banana salad
		Roll and butter
		Baked custard

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CHAPTER XXV

WELL BALANCED DIETS FOR FAMILY GROUPS

In a single family we expect to find differences of age—infants, children, and adults; differences of activity—the liveliest of children and the most sedate of parents; differences of taste—the boy whose sole criterion of a good meal is "enough" and the delicate damsel who cannot even peck at a meal unless the whole setting of the table appeals to her soul. Each member of the family group has his own particular food requirements which are matters of fact not fancy, and yet each claims a seat at the family table; for this is not merely the place where sustenance is furnished for the body; it is also a center of the social life of the group, offering important training in the graces of human intercourse, and in the development of those esthetic standards of choice, preparation, and service of food which are an expression of the culture and refinement of the household.

In the majority of homes, the cost of food is a matter which requires much attention, but spending or saving must be done without impairing the nutritive value of the diet. A distinction must be made between food expenditures for nutriment and those for social purposes. Plain bread and milk make a most nutritious meal at a very low cost, but it is considered too simple and unpretentious to be served at a banquet; it would seem as incongruous as going in a gingham dress or overalls. Each family must determine for itself the relationship between the expenditure for actual nourishment and the additional sum to be allowed for enjoyment and entertainment and maintenance of social prestige.

As it is outside the scope of this book to consider in detail

the social aspects of the food problem, this discussion will be confined to the food requirements of a representative family group, and a plan for meeting them successfully so far as nutrition is concerned.

While the requirements of the individual members may seem to differ considerably, the divergences are more in quantity and mode of service than in kind of food. With minor adjustments, it is possible to keep Six, Sixteen, Thirty-six, and Forty-six well and happy on meals composed of practically the same ingredients, if suitably cooked and apportioned with discretion. Infants and children young enough to require specially prepared food are best cared for by themselves. They are not only likely to have a more carefully selected diet, but the children can also be more comfortably trained in good eating habits.

The energy requirements of the family group will be the sum of those of the individuals composing it. In a family consisting of a father and mother and three young children they might be as follows:

Energy Requirements of a Family with Three Children under Twelve Years of Age

	Weight, Kg.	Calories per Kg.	Calories per Day
Father	70	42	2,940
Mother	56	40	2,240
Boy (10 yrs.)	30	75	2,250
Girl (8 yrs.)	25	70	1,750
Boy (6 yrs.)	18	80	1,440
Total			10,620

A household with older children and parents engaged in heavier manual labor would have higher requirements. This is shown in the following table where seven years of growth on the part of the children have raised their calorie aggregate from 5,440 to 8,860 or 60 per cent; hence with no change in the activity of the adults the requirements at this later time would be increased by an amount equal to adding to the group one hard-working adult man (3,420 calories).

Energy Requirements of a Family with Three Children over Twelve Years of Age

	Weight, Kg.	Calories per Kg.	Calories per Day
Father	70	50	3,500
Mother	56	45	2,520
Boy (17 yrs.)	54	65	3,510
Girl (15 yrs.)	50	47	2,350
Boy (13 yrs.)	40	75	3,000
Total			14,880

Taking from page 506 our first estimate for the family with younger children, we may now state the various food allowances for a balanced diet in terms of shares.

Food Requirements of a Family of Five Expressed in Shares

	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Father	29	29	29	29	29	29	29	29	29
Mother	22	22	22	22	22	22	22	22	22
Boy (10 yrs.)	23	23	43	23	23	23	23	30	23
Girl (8 yrs.)	18	22	43	23	18	20	20	40	20
Boy (6 yrs.)	14	17	43	23	15	20	20	40	20
Total	106	113	180	120	107	114	114	161	114

Moderately Priced Family Dietaries

What selection of food is now going to insure a well balanced diet? The calories cannot be apportioned to our common food groups in the same fashion as for an adult man, nor an adult woman, nor any one of the children. We must have a standard representative of the needs of the group as a whole.

To follow the rule of a quart of milk for each child and a pint for each adult will mean that about one fourth of the total calories will come from this one item. In a moderately priced dietary another fourth, at least, should come from the cereal grains and among foods of this class selection should be made in such a way that at least one half of the calories carry iron and vitamin B. The chief limitation upon fruits and vegetables will be cost. With care in selection, it is usually possible to secure from one sixth to one fifth of the total calories from this group without making the cost

excessive. Dried fruits and vegetables always give a high nutritive return on the money invested, and at certain seasons canned ones are also less expensive than many fresh ones. Fresh fruits and vegetables should never be excluded entirely, but it is well to remember that canned tomatoes, fresh raw cabbage, and potatoes will go far toward supplying vitamin C which is the dietary essential not supplied by ordinary dried fruits and vegetables. If to these are added spinach, string beans, or green peas fresh or canned, carrots and oranges, using potatoes and two of these other vegetables daily, one may rest assured that one sixth of the calories in the form of fruits and vegetables will afford adequate protection, assuming the milk and cereal foods to be chosen as already suggested.

As to fats there is a wide range, but the quantity must not be too large or the diet will be difficult to digest; not too small or some one may fail to get enough calories. In a children's institution it was found that the diet was excellent in almost every other respect, but had a low proportion of fat. Most of the girls grew very well on the diet, but the boys, especially the larger ones, did not, because they did not get sufficiently large servings of the other foods to make up for the lack of fat. Increasing this raised the fuel value without any visible change in the character of the meals, but much to the advantage of the children.

With one fourth of the total calories coming from milk and one sixth from a good assortment of fruits and vegetables, the kind of fat is not as important as where less milk is used, for each quart of milk will yield over an ounce and a half of butter. As butter fat is an important source of vitamin A, it should not be excluded from any diet, but when taken in milk, and supplemented with a small daily portion of cod liver oil, the supply of vitamin A will be well provided for and other fats may be safely used, especially if the vegetables are chosen with regard to vitamin A. Fresh spinach, for instance, weight for weight, has four times as much vitamin A as good butter.

Sugar and syrups, because of their attractive flavor and cheapness, tend to be used too freely in economical diets, displacing foods which are more important. Pure cane molasses is significant for calcium and iron and, in a family where there are growing children, may well be used to replace some cane sugar, but is not a substitute for fruits and vegetables. As Sherman has aptly said: "In general the proper place of sugar in the food supplies and eating habits of children is not in such concentrated forms as candy, nor in the indiscriminate and excessive sweetening of all kinds of foods, but rather as a preservative and flavor to facilitate the introduction into the child's dietary of larger amounts of the fruit and the milk, the importance of which to child health has been increasingly emphasized with each year's progress in our knowledge of nutrition." [1] The total amount of sweets should always be moderate, and from 10 to 12 per cent of the total calories seems to be a very good rule.

Meat is almost invariably one of the most expensive items and since its cost is out of proportion to its nutritive value, it should be used chiefly to give zest to a meal. One half an ounce of meat for a child 8 to 10 years old, one ounce for a child 11 to 14, and two ounces for an older child or grownup, is a very suitable amount for a meal. Liver, which is much richer in iron and vitamins A, B, and G, gives a much better return in nutritive value than muscle meats.

Eggs, although expensive, are especially significant in the diet of young children and should be furnished at least three or four times a week for them even if not provided freely for the adults. When the other food groups have been provided for properly, the proportion of the total calories to be allotted to the meat and egg group will be small.

Cheese may be regarded as a substitute for meat, and is therefore included in this group. But it may also be regarded as a partial substitute for milk, and a part of the calories assigned to milk might be taken as cheese.

[1] Sherman, H. C. "The Problem of Sweets for Children," *Child Health Bulletin*, page 7. American Child Health Association, May, 1929.

Distribution of Calories in a Moderately Priced Dietary

Class of Food	Per Cent of Total Calories
I. Foods from cereal grains (including bread)	25–30
II. Milk	25
III. Vegetables and fruits	15–20
IV. Fats and oils	10–20
V. Sugars	10–12
VI. Meat, eggs, etc.	8–15

The construction of a dietary from such a plan for the distribution of calories is not difficult, as the table below will show:

Selection of Food for a Moderately Priced Family Dietary

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Food to Yield Shares Required	Amount of Food	Number of Calorie Shares
I. Foods from cereal grains (including bread)	25	26	Bread, white	$8\frac{1}{4}$ ounces	6
			Bread, whole wheat	$9\frac{1}{2}$ ounces	7
			Rolled oats, raw	2 cups	6
			Flour, white	$\frac{3}{4}$ cup	3
			Rice	$\frac{1}{2}$ cup	4
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruits	17	18	Prunes	12 medium	3
			Oranges	5 small	3
			Potatoes	6 medium	6
			Lettuce	2 heads	1
			Cabbage	5 cups, shredded	1
			Carrots	3 cups, cubes	4
IV. Fats	15	16	Butter	$5\frac{1}{2}$ ounces	11
			Bacon	$2\frac{1}{2}$ ounces	4
V. Sugar	10	11	Sugar, granulated	$1\frac{1}{3}$ cups	11
VI. Eggs, cheese, meat, etc.	8	8	Eggs	5 eggs	4
			Beef, lean	9 ounces	4

The whole wheat bread and oatmeal are chosen as the half of the calories from cereal foods bearing iron and vitamin B, the fruits and vegetables are all, with the exception of prunes, sources of vitamin C; prunes, lettuce, and carrots are good sources of vitamin A. Bacon has been included with the idea that the bacon fat will be used in cooking. Ten per cent of the total calories means ten ounces of sugar,

which is certainly not restrictive to the point of hardship. One egg has been furnished for each person. That the dietary will meet the estimated requirements of the family is demonstrated by the table following:

A Moderately Priced Family Dietary

Food Materials	Measure	Shares Contributed to the Diet								
		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, white	8¼ oz.	6	8.4	3.0	4.8	4.2	—		—	—
Bread, whole wheat	9½ oz.	7	11.1	6.1	9.9	9.1	+	42.7	—	+
Oats, rolled, cooked	4 cups	6	10.1	4.4	13.4	14.5	—	21.0	—	+
Rice	½ cup	4	3.6	0.5	2.5	2.1				
Flour, white	¾ cup	3	3.8	0.5	2.0	1.7	—	0.3	—	—
Milk, pasteurized	4 quarts	27	51.5	200.6	82.8	18.9	81.0	42.9	46.8	62.5
Prunes	12 medium	3	0.8	2.5	1.8	5.7	20.1	7.5	7.5	13.1
Oranges	5 small	3	2.1	6.9	2.7	6.3	3.9	43.5	177.0	9.5
Potatoes, cooked	6 medium	6	6.3	3.7	8.7	13.2	2.0	28.8	39.0	9.0
Lettuce	2 heads	1	2.7	4.4	5.3	5.9	7.2	21.8	20.0	7.2
Cabbage, raw	5 cups, shredded	1	2.0	6.2	2.4	2.7	1.9	15.9	87.5	8.0
Carrots, cooked	3 cups, cubes	4	3.9	17.8	8.3	10.9	274.0	44.4	19.6	22.4
Butter	5½ oz.	11	0.6	1.3	0.5	0.7	56.1	—	—	—
Bacon	2½ oz.	4	2.7	0.3	1.4	1.6			—	
Sugar	1⅓ cups	11	—	—	—	—	—	—	—	—
Eggs	5 eggs	4	14.5	7.3	13.7	15.6	53.6	15.6	—	19.4
Beef, lean, cooked	9 oz. raw wt.	4	21.8	1.5	12.0	15.2	1.6	9.6	—	12.8
Total		105	144.9	267.0	172.2	128.3	501.4	294.3	397.4	163.9
Standard		106	113.0	180.0	120.0	107.0	114.0	114.0	161.0	114.0

Here again, the need of milk to meet the calcium requirement and to take care of most of the phosphorus is quite readily seen, as is also the importance of choosing the whole grain cereals to make the full quota of iron. Vitamin A is liberally furnished, but since carrots furnish more than half the total some green vegetable or other equally rich source needs to be selected on other days or the vitamin A will drop to a much lower figure. The oranges cover the requirement for vitamin C but the amounts from other foods, while not

large, should be regarded as so much "health insurance." The outstanding value of milk as a source of vitamin G will be seen at a glance. As in all other cases, some special provision must be made for vitamin D, especially for the growing children.

Menu

Breakfast	*Luncheon*	*Dinner*
Oranges	Omelet with bacon	Beef stew with dumplings
Oatmeal	Creamed carrots	Potatoes
Toast and butter	Bread and butter	Bread and butter
Milk to drink	Cabbage salad	Lettuce salad
Coffee for adults	Prune pudding	Rice pudding with milk
	Milk to drink	

This dietary is suitable for the children with a little rearrangement of the menu. The six- and eight-year-olds would have orange juice for breakfast, stewed cabbage instead of the raw salad for luncheon, perhaps the following for supper:

Cream of carrot soup
Toast with a little broth from the stew
Baked potato
Rice pudding
Milk to drink

Family Dietaries with Little Limitation of Cost

As necessity for economy decreases, less cereal food is likely to be used, since this is the least attractively flavored of all types of food in the diet. If the cereals are partly replaced by fruits and vegetables, less attention will have to be devoted to the kind of cereal food used, as the fruits and vegetables will quite regularly increase the mineral and vitamin content of the ration. There may be a tendency to use less milk because of its mild flavor, when many foods of more pronounced flavor can be bought, but even if the fats used are chiefly butter and cream, milk is still needed, since in no other way can liberal calcium be guaranteed. A well-to-do family will find that the following distribution of calories will serve as a guide to a properly assorted diet:

Distribution of Calories in a Dietary without Cost Restrictions

Class of Food	Per Cent of Total Calories
I. Foods from cereal grains (including bread)	18–20
II. Milk	20–25
III. Vegetables and fruits	18–24
IV. Fats and oils	15–20
V. Sugars	10–12
VI. Meats, eggs, cheese, etc.	10–15

Selection of food for the family on this basis might be made as follows:

Selection of Food for a Family Dietary without Cost Restrictions

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Food to Yield Shares Required	Amount of Food	Number of Calorie Shares
I. Food from cereal grains (including bread)	20	21	Farina, dark, raw	$\frac{5}{6}$ cup	5
			Bread, whole wheat	$5\frac{3}{4}$ oz.	4
			Rolls, white	6 rolls	6
			Cookies, plain	10 small	4
			Flour	6 tbsp.	2
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruits	20	21	Grapefruit	2 large	3
			Potatoes	5 med.	5
			Celery	2 cups	$\frac{1}{2}$
			Lettuce	1 head	$\frac{1}{2}$
			Cauliflower	1 head	2
			Bananas	5 med.	5
			Apple	1 large	1
			Tomatoes	$3\frac{1}{2}$ cups	2
			Pineapple, canned	$\frac{1}{2}$ cup	2
IV. Fats and oils	15	16	Butter	$\frac{1}{2}$ cup	8
			Cream	1 cup	8
V. Sugars	10	11	Sugar	$1\frac{1}{3}$ cups	11
VI. Meats, eggs, cheese, etc.	10	10	Eggs	4 eggs	3
			Beef, lean	11 oz.	5
			Cheese	$1\frac{2}{3}$ oz.	2

Menu

Breakfast

Grapefruit
Farina, milk, and sugar
Toast and butter
Coffee with cream for adults
Milk for children

Luncheon

Bouillon
Cheese fondue
Stewed tomatoes
Rolls and butter
Baked bananas
Cookies
Milk to drink

Dinner

Roast beef
Mashed potatoes
Cauliflower
Bread and butter
Lettuce, apple, and celery salad
Junket with pineapple and whipped cream
Milk to drink

In this dietary there will be more need for adjustment to the young children than in the preceding one. Orange juice is preferable for their breakfast on account of its lower acidity. A cream tomato soup with toast squares might form the foundation of the luncheon for the six- and eight-year-olds, with a vegetable saved for the purpose from the previous dinner and plain boiled potatoes. Whole wheat bread should be substituted for the rolls, but the baked bananas and plain cookies would be suitable for dessert.

The younger children's evening meal would probably come before the family dinner. It should also be very simple, consisting perhaps of a creamy egg on toast, whole wheat bread and butter, stewed prunes, and milk to drink.

Very Economical Family Dietaries

Among people of very limited means the largest item in the budget is food, and there must be careful planing to have anything left for other necessities. Food economies can be effected in a variety of ways without sacrifice of nutritive value. The first move should generally be to increase the consumption of the foods from cereal grains, and to see that these are made the carriers of mineral constituents and vitamins so far as they are capable of yielding them. The use of the whole grain instead of the refined product is far more important here than in a diet where cereals constitute one quarter or less of the total calories. The striking lesson that a diet of whole wheat and whole milk with a little added salt is capable of sustaining rats through more than 40 generations should be taken to heart. By skillful cookery it is possible to vary a diet in which cereals figure largely. Mrs. Ewing, a pioneer teacher of home economics and a famous maker of bread, used to say that she could keep any family contented with its meals if she could only make its bread.

Among vegetables and fruits economies must be sought in use of foods at the height of their season and not when out of season and therefore expensive. Purchasing should be done

with regard to nutritive value rather than size or color, but every effort should be made in buying fresh vegetables to have them as fresh as possible, since the flavor depends so much upon this. All the vegetables should be cooked with regard to conserving mineral elements and vitamins, when the quantity is limited. Steaming is often the best method, but it is just as important to cook only a short time if the vitamins are to be conserved.

Milk is always one of the best food investments that it is possible to make. Where fresh milk of good quality is not to be had at a fair price in comparison with other foods, it is now possible to get evaporated milk which can readily be reconstituted by adding an equal volume of water. It loses nothing in the process of condensation of significance except vitamin C and a part of its vitamin B, and this lack can be easily met with orange or tomato juice for infants and young children or by a variety of antiscorbutic fruits and raw vegetables in the diets of other members of the family group. Under some circumstances, dried milk is advantageous. Only water is lost in the drying, and this is replaced almost as easily as in evaporated milk. As a reserve for emergencies, or for safety when traveling, even if fresh milk is ordinarily used, these preparations are worthy of a place in the family larder.

With liberal allowances of milk, and a small daily supply of cod liver oil or its equivalent in vitamin A, butter is not a necessity and money can be saved by letting fat from meat, vegetable oils, and hardened vegetable fats of various kinds largely take its place. There are butter substitutes which are just as wholesome as butter and carry as many calories, though they are not full butter equivalents unless they are definitely known to have vitamin A added in their manufacture to make them equal to butter in this respect.

Cream is always more expensive than milk, and in an economical diet should not be bought as such, but be taken from the milk purchased. The habit of using milk instead of cream on cereals, puddings, etc., is a desirable one to cultivate.

Meat cannot figure prominently in an economical diet since it is usually the most expensive food. Even cheap cuts are not so very cheap, or else they consist largely of waste. Meat is appetizing and therefore a certain amount, especially for adults, is desirable. But the quantity consumed at a meal need not be large, and should be used in such a way as to extend its flavor over as much bread and other bland food as possible, for thus it does its best service. What has been said about eggs and cheese in discussing moderately priced diets also applies here.

Distribution of Calories for a Very Economical Dietary

Class of Food	Per Cent of Total Calories
I. Food from cereal grains (including bread)	30–40
II. Milk	20–25
III. Vegetables and fruits	12–15
IV. Fats and oils	10–12
V. Sugars	10–12
VI. Meats, eggs, cheese, etc.	5–10

Selection of Food for a Very Economical Family Dietary

Class of Food	Per Cent of Total Calories	Calorie Shares Required	Food to Yield Shares Required	Amount of Food	Number of Calorie Shares
I. Food from cereal grains (including bread)	35	37	Flour, white	6 tbsp.	2
			Cornmeal, yellow, raw	6 tbsp.	2
			Rolled oats, raw	2⅝ cups	8
			Bread, whole wheat	14¼ oz.	10
			Bread, white	5½ oz.	4
			Bread, rye	15¼ oz.	11
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruits	12	13	Potatoes	5 med.	5
			Tomatoes	3 med.	1
			Onions	12 med.	3
			Cabbage	11 oz.	1
			Beans, dried, Lima	½ cup	3
IV. Fats and oils	12	13	Butter substitute	3¼ oz.	7
			Vegetable or meat fat	2¾ oz.	6
V. Sugars	10	11	Molasses	½ cup	5
			Sugar, granulated	¾ cup	6
VI. Meat, eggs, cheese, etc.	6	6	Eggs	3 eggs	2
			Beef, lean round	9 oz.	4

MENU

Breakfast	*Luncheon*	*Dinner*
Oatmeal, milk and sugar	Stewed Lima beans	Meat loaf
Toast	Creamed onions	Potatoes
Milk to drink	Rye bread and butter substitute	Scalloped tomatoes
	Indian meal pudding	Cabbage (slaw)
	Milk to drink	Whole wheat bread and butter substitute
		Bread pudding
		Milk to drink

To put such programs into effect means considerable modification of most people's way of thinking about food and of planning meals. Milk has been regarded by too many as food only for babies; one mother expressed a not uncommon idea when she said, "My boy is fourteen years old and I am surprised to find that he can still digest milk!" But year by year the science of nutrition continues to make clearer and clearer that no better foundation for the diet can be found either for children or adults than a liberal amount of milk. Dietaries such as have been outlined in this chapter give little opportunity for fancy cooking. If the suggestions in this book are followed, milk soups, milk puddings, and many other milk dishes will become a prominent part of the régime unless the simpler method of drinking most of the milk is followed by all of the family. Knowledge of how to have a simple diet which is nutritionally the best should help busy housewives to lighten their labors in the kitchen and find time for other interests, such as a larger share in the education of their children. It ought to be a great comfort to a mother to know that she is doing her children a real kindness when she gives them a supper of plain bread and milk or cereal and milk. Scientific knowledge makes possible simplification of the menu without risk of an inadequate diet.

The situation is similar with regard to economy in food. To choose what will fit a slim purse regardless of nutritive value is likely to bring underfeeding on some count or other, perhaps on several counts at once. A common tendency

when money is scarce is to secure calories largely from breadstuffs, sugars and syrups, plus muscle meat, with the result that the dietary is low in mineral constituents and vitamins and not sufficiently laxative.

What can be accomplished when foods are chosen with definite knowledge of what each is contributing is shown by a comparison of the three dietaries at different cost levels which have just been described.

A Comparison of the Nutritive Value of Three Family Dietaries of Differing Cost

Cost Level	Shares Contributed								
	Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
High priced (page 513)	106	147	306	180	126	306	252	873	167
Moderately priced (page 511)	105	145	267	172	128	501	295	397	164
Low priced (page 516)	107	160	273	183	161	154	287	282	124
Standard	106	113	180	120	107	114	114	161	114

Chief Sources of Vitamin A

Foods	High Priced	Moderately Priced	Low Priced
	Shares	Shares	Shares
Cornmeal, yellow	—	—	3.4
Milk	81.0	81.0	81.0
Lettuce	3.6	7.2	—
Celery	1.4	—	—
Carrots	—	274.0	—
Cabbage	—	1.9	1.9
Cauliflower	3.2	—	—
Potatoes	1.5	2.0	1.5
Tomatoes	76.2	—	38.1
Apple	1.2	—	—
Bananas	12.0	—	—
Oranges	—	3.9	—
Prunes	—	20.1	—
Butter	40.8	56.1	—
Cream	32.8	—	—
Beef, lean	2.0	1.6	1.6
Eggs	40.2	53.6	26.8
Cheese	11.6	—	—

Chief Sources of Vitamin B

Foods	High Priced	Moderately Priced	Low Priced
	Shares	Shares	Shares
Bread, whole wheat	24.4	42.7	61.0
Bread, rye	—	—	48.4
Farina, dark	21.0	—	—
Oats, rolled	—	21.0	28.0
Cornmeal	—	—	7.2
Milk	43.2	43.2	43.2
Lettuce	10.9	21.8	—
Carrots	—	44.4	—
Cabbage	—	15.9	15.9
Lima beans, dried, cooked	—	—	18.6
Onions	—	—	6.3
Potatoes	24.0	28.8	24.0
Cauliflower	34.0	—	—
Tomatoes	34.0	—	17.0
Apple	4.0	—	—
Bananas	14.5	—	—
Oranges	—	43.5	—
Grapefruit	12.9	—	—
Pineapple, canned	5.2	—	—
Prunes	—	7.5	—
Beef, lean, cooked	12.0	9.6	9.6
Eggs	11.7	15.6	7.8

Chief Sources of Vitamin C

Foods	High Priced	Moderately Priced	Low Priced
	Shares	Shares	Shares
Milk, pasteurized	6.8	6.8	46.8
Lettuce	10.0	20.0	—
Cauliflower	322.0	—	—
Celery	12.5	—	—
Cabbage, raw	—	87.5	87.5
Onion, cooked	—	—	30.0
Potatoes, cooked	32.5	39.0	32.5
Carrots, cooked	—	19.6	—
Tomatoes	170.0	—	85.0
Apple	8.0	—	—
Grapefruit	207.0	—	—
Bananas	42.5	—	—
Oranges	—	177.0	—
Prunes	—	7.5	—
Pineapple, canned	22.0	—	—

Chief Sources of Vitamin G

Foods	High Priced	Moderately Priced	Low Priced
	Shares	Shares	Shares
Cornmeal	—	—	1.0
Farina, dark	5.5	—	—
Milk	62.4	62.4	62.4
Lettuce	3.6	7.2	—
Cabbage	—	8.0	8.0
Onions	—	—	4.2
Potatoes	7.5	9.0	7.5
Carrots	—	22.4	—
Cauliflower	19.8	—	—
Lima beans, dried	—	—	13.5
Tomatoes	9.8	—	4.9
Apple	1.6	—	—
Bananas	7.5	—	—
Oranges	—	9.5	—
Grapefruit	12.9	—	—
Prunes	—	13.1	—
Pineapple, canned	1.0	—	—
Beef, lean	16.0	12.8	12.8
Eggs	14.7	19.4	9.8
Cheese	4.6	—	—

From these tables it is quite evident that the "Very Economical Dietary" is just as well supplied with protein and mineral elements as either of the others. It is not as rich in vitamin A, and although it will meet all immediate needs for this vitamin, every member of the family will be better off by taking at least one teaspoonful of cod liver oil daily. Through the use of the whole grain cereals the vitamin B content is adequate for ordinary needs. The value of the tomatoes and raw cabbage as sources of vitamin C is attested by the fact that these two foods furnish nearly two thirds of the total day's supply. The importance of milk as a source of vitamin G scarcely needs emphasis after inspection of the figures. If the milk should be reduced it would be more difficult to provide adequate vitamins without increase in cost and the best course would be to make it a rule that every member of the family have a suitable daily portion of tomatoes and of cod liver oil, for vitamins A and C, and a portion of dried brewer's yeast or wheat germ for vitamin G, from which would come also a good supply of vitamin B.

That it will pay to master the art of selecting an adequate diet at any cost level has been the lesson taught by the most careful investigations in the field of nutrition. As Sherman says, "With heredity and all the conditions of environment except food the same, those enjoying the better balanced diet are bound to inherit the earth."

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CHAPTER XXVI

SPECIAL FOOD NEEDS OF MOTHERS AND BABIES

"The baby owes nothing at all to his parents. He has no responsibilities, no duties. The parents owe everything to the baby. Their responsibility to him is complete. Their duties are endless. They are most solemnly bound to use every effort to keep him in good health and happy, to build up his constitution to fit him for the world, and to launch him upon the world. In time their responsibility lessens but it never disappears; whatever happens, it cannot end. In other words, we are bound to see that children are given the best opportunity to develop to the limit of their growth capacity." If we accept this statement by Arnold Bennett as the modern baby's bill of rights, we are solemnly bound to apply all the accumulated knowledge in regard to the nutrition of the growing organism to the problem of feeding the baby.

Good nutrition for the baby begins with the mother. During prenatal life growth goes on at a rate never equaled after birth. The profound effect of diet upon the well-being of the fetus has been repeatedly demonstrated in the case of laboratory animals. Vitamins A, B, and E have each been found to influence gestation in its own specific way. Observations on human life reveal similar effects. Among women in the Philippines found to be suffering from beriberi (due to lack of vitamin B) it is reported that 80 per cent of the pregnancies result in abortion or in death of the child during the first year of life. Reynolds and Macomber have reported cases of women in whom sterility was apparently cured by a change from a diet habitually low in vitamin A to one rich in it. The Wisconsin experiment with cattle showed the disastrous result of several dietary deficiencies in the same ration (for instance

of vitamin A, calcium and sodium chloride in wheat). The influence of a shortage of iodine upon the development of the embryo has been demonstrated not only for various farm animals, but also for the human species. Protracted undernutrition of mothers in central Europe as a result of the World War resulted in a decrease in the weight of the newborn, in a lowering of the capacity for milk production, and in the appearance of rickets in the offspring. If a child is to be well born, the mother's diet throughout pregnancy is a matter of grave importance. Yet the Children's Bureau calls the nine months before a baby is born "the most neglected period of his existence." This is really an indictment of the poor quality of many adult diets, since it is based on the premise that "few mothers get enough of the vitamin and mineral foods needed for health, growth, and the normal regulation of body processes." The proper time to begin to improve the diet of the mother is in her own childhood so that she may come to womanhood with her body well developed and at all times in an optimal state of nutrition. Then the diet of pregnancy need differ only in certain minor details from that to which she has been accustomed.

Nutrition before Birth

Pregnancy is a period of growth and the diet must be relatively rich in all growth promoting substances. There need be, however, no marked increase in the total energy value of the diet. The gain in weight of the fetus is at first scarcely more than one gram per day. By the sixth month it is about 10 grams per day, but about one half of the weight of the newborn is acquired during the last 8 weeks before birth.

Studies of the basal metabolism throughout the gestation period show that it is only in the last three months that the metabolism of the fetus and the increased weight of the mother (amounting to about 20 pounds) have any noteworthy effect upon the total energy requirement of the mother, and then the increase will be almost directly pro-

portional to the increase in body weight. A woman of sedentary habits will require from 2,400 to 2,800 calories per day, while a fairly active one is not likely to need over 2,800 to 3,000.

For the construction of new body tissue there must be available all essential amino acids, hence the quality of the protein of the diet is important. The storage of mineral elements increases as the fetus develops as the following table shows:

Changes in Calcium, Phosphorus, and Iron with the Growth of the Fetus [1]

Age of Fetus Months	Weight of Fetus Kilograms	Calcium Grams	Phosphorus Grams	Iron Grams
4.0	0.522	3.3	2.3	0.042
5.0	0.570	4.0	2.1	0.034
5.5	0.800	4.2	2.8	0.052
6.0	1.165	7.6	4.7	0.084
6.5	1.285	8.0	5.1	0.086
9.0	2.720	28.0	15.0	0.264

The teeth are all under construction before birth. They begin to form by the third month and at birth all the 20 teeth of the first set are inside the jaw and their crowns almost completely calcified. Their normal development depends not only upon mineral elements (especially calcium and phosphorus), but also upon conditions favorable to the utilization of these elements which are insured by liberal amounts of vitamins A, C, and D or the equivalent of D in sunlight or ultra-violet light. The demands for vitamin A are higher in pregnancy than in growth, for it has been shown by Sherman and MacLeod that "a proportion of vitamin A in the food sufficient to support normal growth and maintain every appearance of good health, for a long time at least, may still be insufficient to meet the added nutritive demands of successful reproduction and lactation."

The thyroid gland is specially active in pregnancy and if the mother has been living on the margin of safety as regards iodine the gland may enlarge in an effort to perform its

[1] Compiled from data cited by Feldman, W. M. *Principles of Ante-natal and Post-natal Child Physiology*, page 130. Longmans, Green and Co. (1920).

functions without an adequate supply. In the Goiter Belt, iodine should be given throughout pregnancy to prevent goiter in the baby as well as in the mother. Iodized table salt may be used, but administration of iodine in suitable form and dosage by a physician is preferable.

During pregnancy the mother must eliminate the waste products from the unborn child in addition to those from her own body, and it is important that this be facilitated by a relatively large proportion of liquids. At least two quarts of fluid should be taken daily. One quart should be milk and of the remainder a considerable part may well be fruit juice, or broths made with vegetable juices. When fresh milk is not available, milk powder or evaporated milk should take its place. The milk will insure protein of good quality. Meat should be used sparingly so that the total protein intake may not exceed 10 per cent of the total calories, lest the kidneys be overtaxed.

The diet will also need to be more laxative than usual. Liberal amounts of fresh fruits, and leafy vegetables, with whole wheat bread, bran breakfast foods, and bran bread are most desirable at this time, not only for laxative effect but for mineral salts and vitamins. Care should be taken in their selection to secure a liberal supply of vitamins A, B, C, and G. In addition to a well regulated diet, the prospective mother should spend several hours each day out of doors exposed to bright sunshine. If the locality or the season makes this impossible, she should take at least one tablespoon of cod liver oil daily as a source of vitamin D. The diet of the pregnant woman cannot safely be left to chance. Many women at the beginning of pregnancy are in a state of undernutrition and may require a considerable increase in both energy-yielding and body-building and regulating foods.

The Nutrition of the Nursing Mother

When the baby is born, the demand upon the mother for nourishment does not cease; it merely takes another form, and continues to increase with the growth of the child. The

secretion of the mammary gland is wonderfully adapted to the needs of the offspring. It is impossible to find an adequate substitute, and the work the baby has to do to get his food is advantageous in bringing a good supply of blood to the muscles of mouth, nose, and throat; in producing a well formed arch for the roof of the mouth and well developed jaws to hold the second teeth without overlapping and irregularity. It is also believed to help in the development of the abdominal muscles; at least breast fed babies seem less likely to have protruding abdomens than the artificially fed. Every well nourished mother with proper instruction should be able to nurse her baby.[1] But it is not to be expected that a mother may entirely overcome bad habits of diet throughout all her previous life in a few days or weeks after lactation has begun. In pregnancy, preparation for lactation begins and adequate nutrition throughout the gestation period should enable a mother to meet more successfully the strain of lactation.

Quantitatively, the demands on the mother grow greater day by day. A baby a week old may need only 16 ounces of milk in 24 hours, but three weeks later may be taking 28 or 30 ounces. Twenty-eight ounces of milk means about 560 calories. These must be secured from the food eaten by the mother, or else taken from the fuel reserves of her own body. Oftentimes mothers lose weight during the lactating period or fail to produce milk to full capacity because of insufficient food. It would seem reasonable to allow the mother in the first three months, as additional fuel for the milk supply, 60 calories per day for each pound of the baby's weight, in the second three months about 50 calories per pound, and for the next three months not less than 40 or 45 calories per pound.

To furnish the protein represented in the milk, there should be added to the mother's diet at least two protein calories for each protein calorie withdrawn in the milk.

[1] Helpful advice may be found in *Infant Care* by Mrs. Max West, Children's Bureau, United States Department of Labor, or in *Mother and Child* by C. U. Moore, J. B. Lippincott Co., 1927, if a physician is not available.

The calcium requirement of a nursing mother supplying 30 ounces of milk per day is nearly twice as high as it is under ordinary conditions, and her phosphorus requirement is increased at least one fourth. The needs for extra protein, calcium, and phosphorus are most efficiently met by the liberal use of milk.

The baby's need of vitamins must also be met at least in part by the mother's milk. It has been shown that the amount of any vitamin in milk depends directly upon the food, since vitamins are not manufactured in the mother's body. Even though vitamins A and G can be stored, they should be liberal in the diet all the time, since it would be a distinct disadvantage to the mother to give up her reserves. Vitamins B and C also need to be plentiful every day, since there will be little or no body store of either to draw upon. Vitamin D in mother's milk may be increased by irradiation of the mother with ultra-violet light, but it is now customary to give babies cod liver oil before the end of the first month.

The Baby

The normal child of a well nourished mother, although requiring constant and intelligent care, should not be a nutritional problem. Nature provides the ideal nourishment in the secretion of the mammary gland, which in response to the sucking of the child, yields nutriment proportional to that demand. The vigorous child thus assures his own supply; the delicate child may be the victim of insufficient food because he cannot "work his way" so well. Today such infants are helped along by manual stimulation of the gland, whereby milk is furnished the baby and the supply is kept up until greater strength enables him to draw enough for his needs.

The most important considerations for the breast fed baby are therefore:

(1) A well nourished mother.
(2) Strength to draw milk as needed or help if strength is inadequate.

(3) Conditions of life which make it possible to digest the food eaten, and sunshine.
(4) Adequate rest, freedom of movement, fresh air, to insure the best use of food absorbed.

(1) A well nourished mother must have not only the food required to maintain herself, but in addition the equivalent of the food material given to the baby as milk every day.

(2) The digestive tract of a baby is very delicate and has a great deal of work to do because of the relatively high food needs of this period of very rapid growth. An upset means loss of food that can ill be spared, and disturbance of the tract itself which may lead to irritability, acute indigestion or, if long continued, to chronic malnutrition. Regularity of meals is of prime importance. Intervals between meals must be neither too short nor too long. The milk will be more uniform in quality, and intervals of rest for the stomach aid appetite and digestion. A practical schedule is suggested on page 531, but a mother (especially with her first child) appreciates the advice of a physician skilled in the care of babies, and should have it if possible either from a private physician or from a member of the staff of a baby health station or child welfare clinic. Every day is significant in a little baby's life, and expert supervision makes possible the finest adjustment of the daily program to the needs of the greatest individualist in the world—the baby.

(3) Without adequate rest growth is impossible. The newborn child sleeps the greater part of the twenty-four hours. At six months of age, it still sleeps sixteen to eighteen hours, and at the end of a year, about fourteen hours. When not sleeping, the very young baby should lie in a comfortable bed, free to move but not moved by some one else, except when feeding or change of clothing makes handling necessary. When the child is old enough to sit up, care must be taken to guard against overdoing the new accomplishment. At the least sign of fretting it may be well to lay the baby upon its bed. There is no better place to rest and no more comfortable place to cry.

Fresh air is the best of tonics and the necessity for sunshine has been pointed out in connection with the discussion of vitamin D and rickets in Chapter XIII. As an additional safeguard, the routine use of cod liver oil has proven of great advantage to all babies beginning about the second week of life with a drop or two and increasing the amount very gradually. Plenty of vitamin D thus supplied may mean the difference between good teeth and bad, between a well coordinated set of joints to promote good posture, and knock-knees, flat feet, and other hindrances to easy standing and walking; or (for the girl) between a well developed pelvis and easy maternity or a poorly developed one and perilous motherhood. There is nothing to lose and a chance of much to gain by its use.

Supplementary Foods for the Breast Fed Baby

In the sixteenth century mothers were advised not to wean their children until they had all their teeth. Today in the United States it is usually possible to wean a baby before it is a year old. By the ninth month it is usually strong enough that the inevitable differences between the best "artificial" diet and mother's milk need not be a serious obstacle to success. A very young baby is in danger of having his digestion upset by any food but his mother's milk. In case of misfortune, we must do the best we can, but it is usually best to give the baby the benefit of his mother's milk through the first nine months of his life.

This does not mean, however, that we are to let the baby subsist exclusively on his mother's milk for nine months and then abruptly change to other food. Such a course is fraught with peril if not disaster. Preparation for weaning should start early and the baby should gradually be accustomed to the foods which are to be his diet when weaning is fully accomplished. Since babies in the temperate zone, especially if born in the fall, are liable to rickets, it is well to begin giving a drop or two of cod liver oil about two weeks after birth. At the age of one month one fourth to one half teaspoonful may be given twice a day between two breast feedings and

by the age of three months this can be increased to a teaspoonful twice a day.

The next addition should reinforce the mother's milk with regard to vitamin C since this in liberal amounts may be favorable to the development of the teeth, and may protect against subacute scurvy. For this purpose a teaspoonful of strained orange juice or tomato juice is most suitable, and may be introduced at the beginning of the second month, between two breast feedings.

As the next step in training the baby to a mixed diet, a cooked cereal jelly is desirable. A teaspoonful or two, cooked very soft, strained, and seasoned lightly with salt, may be given at the time of a morning and evening feeding. The main object at this time being to establish the habit of eating cereals, regularity of feeding is more important than the quantity fed. When the habit is well established the quantity can easily be increased.

By the fourth month, half a teaspoonful of egg yolk may be given with the 2 P. M. feeding.

A further step in training the baby to other foods may be taken in the fifth month by adding a little cooked and sifted green vegetable, at a feeding when cereal is not given. Preference should be given to those vegetables rich in iron, such as spinach, peas, or carrots, and in this instance also a teaspoonful is sufficient for the first few weeks after vegetables are introduced into the diet, gradually increasing to a tablespoonful of sifted pulp.

In the sixth month fruit pulp may be added to the daily program, beginning with a teaspoonful and increasing gradually to one or two tablespoonfuls.

When several teeth come, a crust of bread may be given at the conclusion of one feeding to start training in mastication. By the time these various steps have been taken, it will be possible to substitute cow's milk for one breast feeding and shortly thereafter to substitute a second feeding of cow's milk, after which complete weaning should be comparatively easy.

From the outset, regularity in the feeding schedule is of the greatest importance, as it not only helps to maintain a milk supply of uniform quality, but also assists in keeping the baby's digestive tract in good condition by suitable intervals of rest between meals. As a rule, intervals between meals should be not less than three hours, and after a baby is three months old (if not sooner) may be lengthened to four hours. Cool boiled water should be given regularly between feedings, as the baby's water needs are high. Whatever the schedule decided upon, it should be scrupulously adhered to just as long as it is in effect.

The night's rest of the mother should be broken as little as possible. Most babies are now trained to sleep from midnight to morning without nursing, and after the age of three months, the last feeding may be given at 10 P. M.

The characteristic changes in the feeding program from birth through weaning time are shown in the following schedule:

Daily Program for Breast Fed Babies

First Month: Breast feedings at 2, 6, 10 A. M., 2, 6, 10 P. M.
At second week, 2 drops of cod liver oil daily with one breast feeding, increasing gradually to $\frac{1}{4}$ teaspoon by fourth week.

Second Month: Omit 2 A. M. breast feeding.
Add 1 teaspoon orange juice mixed with 1 teaspoon water one hour before 10 A. M. feeding. Increase gradually to 1 tablespoon of orange juice, at same time decreasing water till orange juice is given undiluted at end of month.
Give $\frac{1}{4}$ teaspoon cod liver oil daily, increasing gradually to 1 teaspoon.

Third Month: Increase cod liver oil gradually from 1 teaspoon to 2 teaspoons daily, and orange juice from 1 tablespoon to 2 tablespoons.

Fourth Month: Add 1 teaspoon cooked cereal with 10 A. M. feeding and 1 teaspoon with 6 P. M. feeding. Increase gradually to 2 tablespoons at each of these feedings. Substitute 1 bottle for 2 P. M. breast feeding. Omit 10 P. M. feeding.
Add $\frac{1}{2}$ teaspoon egg yolk with 2 P. M. feeding increasing gradually to yolk of one egg.

Fifth Month: Add 1 teaspoon vegetable pulp with 2 P. M. feeding. (Spinach, carrots, peas, or a mixture of these), increasing gradually to 1 tablespoon.

Sixth Month: Add 1 teaspoon fruit pulp, increasing gradually to 2 tablespoons with 2 P. M. feeding. (Apples, prunes, apricots, ripe bananas.)

Seventh Month: Add 1 tablespoon baked potato to 6 P. M. feeding and 1 piece of bread crust or zwieback after 10 A. M. feeding.

Eighth Month: Meals at 7 A. M., 12 P. M., and 5:30 or 6 P. M.

On waking, 3–4 tablespoons orange juice.

Breakfast 6 oz. milk to drink.
3 to 5 tbsp. cooked cereal with 2 oz. milk.
1 small piece zwieback or stale bread to chew.

Dinner 1 egg yolk.
2 to 4 tbsps. sifted vegetable pulp.
2 to 4 tbsps. baked potato with ¼ tsp. butter.
2 to 4 tbsps. stewed fruit pulp.
6 to 8 oz. milk to drink.
1 small piece stale bread to chew.

Supper 8 oz. milk to drink.
3 to 5 tbsps. cooked cereal with 2 oz. milk.

Ninth to Twelfth Month: Continue the same program, increasing amounts of cereals, vegetable and fruit pulp gradually as the child grows. Rice or macaroni may be substituted now and then for potato if desired. One to 2 teaspoons of finely chopped liver may be substituted once or twice a week for egg yolk.

Artificial Feeding of Well Babies

No matter how strong our convictions as to the importance for the baby of breast feeding through the major portion of the first year, we cannot shut our eyes to the fact that circumstances may arise which make the substitution of some other form of nourishment imperative. It behooves us therefore to be prepared to deal intelligently with such emergencies.

In its essence, the problem of planning a diet for a baby is not very different from that of a diet for any growing child. There is the same need of an adequate supply of calories; of protein, with growth sustaining amino acids; of an assortment of mineral elements and vitamins each suit-

able in amount for rapid growth; and of a liberal supply of water. As shown in Chapter V, the total energy requirement during the first year of life is about 100 calories per kilogram of body weight, and as pointed out in Chapter VII, the protein needs of this period will be best met when from 10 to 15 per cent of the total calories (or at least one protein share for every calorie share) are from proteins of the best quality. The relatively high requirements for mineral elements and vitamins have already been discussed in detail in Chapters VIII–XV and the daily program for the one-year-old child in Chapter XXIII.

The special problems of artificial feeding in infancy lie chiefly in making the diet sufficiently easy to digest. Any food but mother's milk is a risk in the stomach of the young baby. The selection of foods which will meet all the quantitative requirements, the arrangement of the feeding schedule, the way in which the meals are prepared and fed, in fact the whole daily régime of the baby must have the most careful consideration in every detail if the venture is to be successful. The younger the baby, the more difficult the task. Whenever any mother's milk is available it should be used, even if it is not enough and has to be supplemented by other food.

The best foundation for the artificially fed baby's diet is clean, pasteurized cow's milk of the best quality or its equivalent of evaporated (unsweetened) milk. An ounce and a half of milk per pound of the baby's weight will furnish the requisite protein and the major portion of the total calories. To this must be added some easily digested carbohydrate food, the best choice being milk sugar or a mixture of maltose and dextrin such as corn syrup or dextrimaltose, not very sweet cane sugar. From this the calories needed in addition to those furnished by the milk are derived.

Water must be added to the milk and carbohydrate mixture, because without it the food will be too hard for the baby to digest. It is a good rule to allow about 3 ounces of fluid per pound of baby for a child under 4 months of age, about $2\frac{1}{2}$ ounces per pound for a baby 4 to 6 months old; and

thereafter to decrease the amount of water gradually until in the latter part of the first year, undiluted milk can be taken safely. The water to be used may therefore be calculated by deducting from the total amount of food, the volume of milk used. Thus a baby weighing 16 pounds and needing 24 ounces of milk but 36 ounces of fluid should have 12 ounces of water added to the milk.

The milk-carbohydrate-water mixture must be prepared carefully by measure each day, and divided equally among the feeding bottles which represent the number of feedings to be given in 24 hours. These bottles must be sterilized before using, and the food mixture should be quickly brought to the boiling point before putting it into the bottles. When the requisite amount of food has been put in, they should be stoppered with sterilized cotton or covered with sterilized caps of glass or rubber and kept cool till needed. At feeding time, one bottle should be quickly warmed to body temperature and fed without delay.

When cow's milk has been thus modified for the sake of ease of digestion and to furnish calories sufficient for the baby's energy requirement, consideration must still be given to the other essentials of the fully adequate diet. The cow's milk, if taken in the amounts suggested per pound of baby, will furnish sufficient protein, calcium and phosphorus, but the iron supply will be too low, and at least by the beginning of the third or fourth month some definite source of iron should be provided. At first this may be some iron-bearing cereal food, specially prepared for infants; a little later egg yolk and green vegetable pulp will serve as additional sources.

Since the vitamin C furnished by milk is uncertain, a supplementary source should be supplied routinely from the second or third week, orange or tomato juice serving admirably for this purpose. The amount is necessarily small at first, but can be increased as the child grows. Vitamin D must also be provided from the outset and cod liver oil is usually the preferred source because it will also furnish liberal amounts of vitamin A, which if not immediately

needed for growth, can be stored in the tissues, thus enhancing their vigor and ability to resist infections of many kinds. Exposure to sunlight is always a desirable part of the daily program, not only for its antirachitic effect, but for other healthful influences. Diluted cow's milk does not furnish sufficient vitamin B for the maintenance of a baby's best health, hence some special source of this vitamin should be added. A special cereal with added wheat germ as well as iron is obtainable, and can be used for the cereal jelly. Other good sources are an extract of wheat germ on soluble carbohydrate material known as vitavose or a yeast extract called vegex, either of which can be obtained at moderate cost and added in suitable small amounts to the milk formula. Other preparations of vitamin B are also obtainable.

The schedule on page 536 illustrates the application of these principles. The foods are given in quantities for 24 hours, and in addition to the number of feedings the total amount of fluid for each feeding is stated in ounces. If there should be a tendency to constipation a little prune juice may be mixed with the orange juice, or the amount of vitamin B very cautiously increased. The best way to determine whether the total calories are sufficient is by study of the weekly weight record to see whether good progress is made. If a baby does not gain at a normal rate, a systematic search should be made to find the cause. Every mother should have at least one handbook on child care [1] and should secure advice from a physician expert in the care of babies, either privately or at a baby health station or other health center. It pays to take the best possible care to start the baby right, and foster from the beginning those habits which promote health and vigor. The reward will come partly in the present, in a healthy, happy baby which is a delight instead of a worry, but more in the future when to the grown man or woman, the full reward comes in the enjoyment of a vigorous adult life and deferred old age.

[1] *Infant Care*, published by the Children's Bureau, United States Department of Labor, Washington, D. C., will be furnished free on request.

SCHEDULE FOR ARTIFICIAL FEEDING OF WELL BABIES BASED ON AVERAGE WEIGHT FOR AGE IN QUANTITIES FOR 24 HOURS

Age	No. Feedings	Amount per Feeding, Oz.	Whole Milk, Oz.	Water, Oz.	Milk Sugar [a]	Orange Juice	Cereal Jelly [b]	Stale Bread, Toast, or Zwieback	Green Vegetable Pulp	Egg Yolk	Cod Liver Oil
Days											
5, 6, 7	6	2½	5	10	1 tbsp.						
8–14	6	3⅓	8	12	1 "						¼ tsp.
Weeks											
2–4	6	4	9	15	1 "	⅓ tbsp.					½ "
Months (beginning of)											
2	5	4⅓	10	16	1 tbsp.	½ tbsp.					1 "
3	5	5½	13	15	1¼ "	1 "	½ tbsp.				2 "
4	4	6¼	17	9	1½ "	2 "	⅔ "		⅓ tbsp.		2 "
5	4	7	21	7	1½ "	2 "	1 "		1 "	½	2 "
6	4	7½	23	7	1½ "	2½ "	2 "	small piece	2 "	½	2 "
7	4	7½	25	5	1½ "	3 "	3 "	1 slice	2 "	1	2 "
8	4	8	27	5	1½ "	3 "	4 "	1 "	2 "	1	2 "
9	4	8	27	5	1½ "	4 "	4 "	1 "	2 "	1	2 "
10	4	8	32	0	1½ "	5 "	4 "	1 "	3 "	1	2 "
11	4	8	32	0	1 "	6 "	5 "	1 "	4 "	1	2 "
12	4	8	32	0	1 "	6 "	6 "	1 "	5 "	1	2 "

[a] Dextrimaltose may be substituted wholly or in part and is better digested by some babies. It is a little lighter than milk sugar, hence in using it, increase the quantities in the proportion of one teaspoonful for each tablespoonful in the schedule. Until cereal jelly is added, some source of vitamin B should be added along with the milk sugar.

[b] This should be chosen to furnish vitamin B and iron unless these are otherwise provided for.

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APPENDIX

APPENDIX

TABLE I

Nutritive Values of Foods in Shares

1 Energy Share	=	100 calories
1 Protein Share	=	2.5 grams or 10 calories
1 Calcium Share	=	0.023 gram
1 Phosphorus Share	=	0.044 gram
1 Iron Share	=	0.0005 gram
1 Vitamin A Share	=	100 Sherman-Munsell units
1 Vitamin B Share	=	10 Sherman-Chase units
1 Vitamin C Share	=	2 Sherman-La Mer units
1 Vitamin G Share	=	20 Sherman-Bourquin units

Vitamins have been stated in shares wherever possible. Otherwise signs have been used as follows:

+, the vitamin is present

++, the food is a good source of the vitamin

+++, the food is an excellent source of the vitamin

–, the food contains no appreciable amount of the vitamin

A blank means that no definite information is available

The letters (R) and (CK) after vitamin values indicate raw and cooked respectively

A. P. means as purchased

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Almonds, chocolate	16	0.6	4–8 nuts	1.00								
Almonds, salted	15	0.5	10–12 nuts	1.00								
Almonds, shelled		1.0		1.81	2.4	3.1	2.9	2.2	+	2.3	—	
		3.5	7/8 cup	6.39	8.4	11.0	10.3	7.8		8.0		
	16	0.6	12–15 nuts	1.00	1.3	1.7	1.6	1.2		1.3		
Apple, baked		1.0		0.29	—	0.1	0.1	0.2	0.2	0.7	—	0.3
		3.5		1.21	0.2	0.3	0.3	0.6	0.7	2.4	—	1.0
	83	2.9	1/2 large apple	1.00	0.1	0.3	0.2	0.5	0.6	2.0	—	0.8
	165	5.8	1 large apple	2.00	0.3	0.5	0.5	1.0	1.2	4.0	1	1.6
Apple pie		1.0		0.54	0.2	0.1	0.1	0.2	0.2	0.4	—	0.2
		3.5		2.30	0.9	0.4	0.6	0.8	0.9	1.6		0.8
	52	1.8	1½″ sector, 9″ diam.	1.00	0.4	0.2	0.3	0.4	0.4	0.7		0.4
	157	5.5	4½″ sector, 9″ diam.	3.00	1.3	0.5	0.8	1.0	1.0	2.1		1.1
Apple sauce		1.0		0.28	—	—	—	0.1	0.1	0.7	—	0.3
		3.5	3/8 cup	1.00	0.1	0.2	0.2	0.4	0.4	2.1	—	0.9
	126	4.4	1/2 cup	1.33	0.2	0.3	0.3	0.6	0.5	3.0	1	1.1

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Apples		1.0		0.18	—	0.1	0.1	0.2	0.2	0.7	2*	0.3
		3.5	1 small, 2″ diam.	0.63	0.2	0.3	0.3	0.8	0.8	2.5	5*	1.0
	127	4.5	1 med., $2\frac{3}{4}$″ diam.	0.80	0.2	0.4	0.3	0.9	1.0	3.2	6*	1.3
	159 (212 A. P.)	5.6	1 large, $3\frac{1}{4}$″ diam.	1.00	0.3	0.6	0.4	1.1	1.2	4.0	8*	1.6
Apricots, canned		1.0		0.21	0.1	0.1	0.1	0.2				
		3.5	2 large halves $1\frac{1}{3}$ tbsp. juice	0.73	0.3	0.4	0.4	0.7				
	137	4.9	3 large halves 2 tbsp. juice	1.00	0.5	0.6	0.6	1.0				
Apricots, dried		1.0		0.79	0.5	0.8	0.8	4.3	19.9	+	6†	1.4‡
		3.5	25 halves	2.78	1.9	2.9	2.7	15.2	70.0		20†	4.8‡
	36	1.3	9 halves	1.00	0.7	1.0	1.0	5.5	25.2		7†	1.7‡
Apricots, fresh		1.0		0.16	0.1	0.2	0.2	0.3	15.3	+	1(R)§	0.6
		3.5	3 apricots	0.57	0.4	0.6	0.6	1.2	54.0		3(R)§	2.1
	177	6.2	5 apricots	1.00	0.7	1.0	1.0	2.1	95.6		6(R)§	3.7
Artichokes, French or globe		1.0		0.18	0.3	0.5	0.6	0.5	0.9	+	3	
		3.5		0.63	1.2	1.7	2.1	1.9	3.0		9	
	159	5.6		1.00	1.8	2.8	3.4	3.0	4.8		15	
	250	8.8	1 artichoke	1.58	3.0	4.3	5.3	4.8	7.5		22	

* Value for Northern Spy, Spitzenberg, and Stayman Winesap.
‡ Sulfured: unsulfured 30 per cent higher.
† Sulfured: unsulfured one-half as much.
§ 30 to 80 per cent lost in cooking.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Asparagus,		1.0		0.07	0.3	0.3	0.3	0.6	2.0	++	2(CK)	++
green		3.5	12 stalks, 5″ long	0.26	0.9	0.9	0.9	2.0	7.0		6(CK)	
	381	13.5	46 stalks, 5″ long	1.00	3.4	3.5	3.4	7.6	26.7		23(CK)	
Avocado,		1.0		0.30	0.2	0.6	0.3	3.6	1.4	2.8	3	0.8
West Indian		3.5	$\frac{1}{2}$ pear, $\frac{2}{3}$ cup, $\frac{1}{2}$″ cubes	1.06	0.7	2.0	1.0	12.6	5.0	10.0	9	2.8
	94	3.3	$\frac{5}{8}$ cup, $\frac{1}{2}$″ cubes	1.00	0.5	1.8	0.9	11.9	4.7	9.4	8	2.6
Avocado,		1.0		0.75	0.2	0.4	0.9	0.8	0.3	2.8	3	0.8
native		3.5		2.65	0.7	1.3	3.1	2.8	1.1	10.0	10	2.8
(Fuerte)	38	1.3	$\frac{1}{6}$ pear, $\frac{1}{4}$ cup, $\frac{1}{2}$″ cubes	1.00	0.3	0.5	1.2	1.1	0.4	3.8	4	1.0
Bacon, broiled	15	0.5	4–5 small slices	1.00	1.3	0.1	0.8	1.0	—	—	—	0.3
Bacon,		1.0		1.77	1.2	0.1	0.6	0.8	0.1	+	—	0.6
uncooked		3.5	10 slices, $1\frac{1}{2}$″x$4\frac{1}{2}$″x$\frac{1}{8}$″	6.25	4.2	0.3	2.3	2.6	0.2			2.0
	16	0.6	$1\frac{1}{2}$ slices, $1\frac{1}{2}$″x$4\frac{1}{2}$″x$\frac{1}{8}$″	1.00	0.7	0.1	0.4	0.4	—			0.3
Bamboo		1.0		0.09	0.3	0.1	0.4	0.4				
shoots		3.5	$\frac{2}{3}$ cup, 1″ pyramids	0.33	1.0	0.3	1.3	1.4				
	303	10.7	2 cups, 1″ pyramids	1.00	3.0	0.9	4.1	4.2				
Bananas		1.0		0.28	0.2	0.1	0.2	0.4	0.7	0.8	3	0.5
	100 (156 A.P.)	3.5	1 medium	1.00	0.5	0.4	0.7	1.3	2.4	2.9	9	1.5

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight: Gms.	Weight: Oz.	Approximate Measure	Shares: Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bass,		1.0		0.35	2.2	0.6	1.4	0.4	−	+	−	+
steamed		3.5	1 piece, 3″x2$\frac{3}{4}$″x1″	1.24	7.7	2.1	4.9	1.4				
	81	2.9	1 piece, 3″x2$\frac{1}{4}$″x1″	1.00	6.3	1.7	4.0	1.1				
Bean curd,		1.0		0.19	1.0	2.3	0.6	1.4			−	
soy		3.5	1 portion, 2$\frac{3}{4}$″x2$\frac{1}{2}$″x1″	0.67	3.4	8.3	2.3	5.0				
	150	5.3	1$\frac{1}{2}$ portions	1.00	5.0	12.4	3.4	7.5				
Bean sprouts,		1.0		0.09	0.4	0.5	0.4	0.6	0.1	0.6	6	
mung		3.5	1 cup	0.32	1.3	1.8	1.2	2.0	0.3	2.0	20	
(root re-	312	11.0	3 cups	1.00	4.0	5.7	3.8	6.2	0.8	6.2	63	
moved)												
Beans, baked,		1.0		0.37	0.8	0.8	1.2	1.2				
canned		3.5	$\frac{1}{2}$ cup (scant)	1.29	2.7	2.7	4.2	4.1				
	78	2.7	$\frac{1}{3}$ cup	1.00	2.1	2.1	3.3	3.2				
Beans, kidney		1.0		0.98	2.3	1.9	3.1	4.5	0.2	7.1	−	+
dried		3.5	$\frac{1}{2}$ cup	3.47	8.0	6.1	10.8	14.4	0.5	25.0		
	29	1.0	$\frac{1}{8}$ cup (scant)	1.00	2.3	1.9	3.2	4.6	0.2	7.3		
Beans, Lima,		1.0		0.99	2.1	0.9	2.5	5.5	+	6.5(CK)*	−	4.5
dried		3.5	$\frac{2}{3}$ cup	3.50	7.2	3.2	8.8	19.4		22.8(CK)*		15.8
	29	1.0	$\frac{1}{6}$ cup	1.00	2.1	0.9	2.5	5.6		6.5(CK)*		4.5
	156	5.5	1 cup	5.46	11.3	5.0	13.7	30.3		35.6(CK)*		24.6

* 30 per cent lost in cooking when all water retained.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Beans, Lima, fresh		1.0		0.35	0.8	0.3	0.9	1.4	+	3.2(CK)*	5(CK)	1.4
		3.5	$\frac{5}{8}$ cup	1.23	2.8	1.2	3.0	4.8		11.5(CK)*	15(CK)	5.0
	81	2.9	$\frac{1}{2}$ cup	1.00	2.4	1.0	2.5	3.9		9.2(CK)*	12(CK)	4.0
Beans, navy, dried		1.0		0.98	2.6	1.8	3.0	5.7	0.2	7.1	—	+
		3.5	$\frac{1}{2}$ cup	3.45	9.0	6.4	10.5	20.0	0.5	25.0		
	29	1.0	$\frac{1}{8}$ cup (scant)	1.00	2.6	1.9	3.0	5.8	0.2	7.1		
	200	7.0	1 cup	6.84	17.9	12.9	21.0	40.0	1.1	48.5		
Beans, soy, yellow, dried		1.0		0.97	4.5	2.9	4.3	3.8	+	14.2	—	12.8
		3.5	$\frac{1}{2}$ cup	3.43	15.7	10.2	15.2	13.4		50.0		45.0
	29	1.0	$\frac{1}{8}$ cup	1.00	4.6	3.0	4.4	3.9		14.5		13.1
Beans, string, green, fresh		1.0		0.12	0.3	0.7	0.3	0.6	2.8	0.9	1(CK)	0.4
		3.5	$\frac{3}{4}$ cup, 1″ pieces	0.42	0.9	2.4	1.2	2.3	10.0	3.2	5(CK)	1.3
	241	8.5	$2\frac{1}{3}$ cups, 1″ pieces	1.00	2.2	5.8	2.9	5.3	24.1	8.0	11(CK)	3.0
Beans, string, green, strained, canned		1.0		0.07	0.1	0.4	0.2	0.6	1.8	0.5	1	0.3
	128	4.5	$\frac{1}{2}$ cup	0.30	0.6	2.0	0.8	2.5	8.2	2.4	4	1.4
	15	0.5	1 tbsp.	0.04	0.1	0.2	0.1	0.3	1.0	0.3	—	0.2
Beef, corned, canned		1.0		0.64	2.5	0.2	0.8	5.6	+	+	—	++
		3.5	1 piece, 3″x2″x1″	2.24	8.9	0.6	2.7	19.6				
	45	1.6	1 piece, 3″x2″x$\frac{1}{2}$″	1.00	4.0	0.3	1.2	8.7				

* 25 per cent lost in cooking when all water retained.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Beef, dried		1.0		0.51	3.4	0.2	2.1	2.5	+			++
		3.5	7 thin slices, 4"x5"	1.80	12.0	0.8	7.4	9.0				
	56	2.0	4 thin slices, 4"x5"	1.00	6.7	0.4	4.1	5.0				
Beef, round, lean		1.0		0.44	2.4	0.2	1.3	1.7	0.2	1.4	−	1.4
		3.5	1 piece, $2\frac{1}{2}$"x$2\frac{1}{2}$"x$\frac{3}{4}$"	1.56	8.5	0.5	4.6	6.0	0.7	5.0		5.0
	64	2.3	1 piece, $2\frac{1}{2}$"x$1\frac{3}{4}$"x$\frac{3}{4}$"	1.00	5.5	0.4	3.0	3.8	0.4	3.2		3.2
Beef, rump steak, broiled		1.0		0.84	2.9	0.1	2.0	2.9	+	+	−	++
		3.5	1 piece, 4"x3"x$\frac{5}{8}$"	2.95	10.1	0.4	6.9	10.4				
	34	1.2	1 piece, 4"x1"x$\frac{5}{8}$"	1.00	3.4	0.1	2.3	3.5				
Beef, sirloin, roast		1.0		0.62	3.0	0.1	1.8	4.9	+	+	−	++
		3.5	2 slices, 5"x$2\frac{1}{2}$"x$\frac{1}{4}$"	2.18	10.7	0.3	6.5	17.4				
	46	1.6	1 slice, 5"x$2\frac{1}{2}$"x$\frac{1}{4}$"	1.00	4.9	0.1	3.0	8.0				
Beet greens		1.0		0.09	0.2	1.2	0.3	1.8	+++	++	+	3.5
		3.5	$\frac{1}{2}$ cup, steamed	0.33	0.7	7.2	1.1	6.3				12.5
	302	10.6	$1\frac{1}{2}$ cups, steamed	1.00	2.4	12.4	2.8	19.6				37.8
Beets		1.0		0.13	0.2	0.3	0.3	0.5	0.1	0.3	1(CK)	0.7
		3.5	2 beets, 2" diam. or $\frac{1}{2}$ cup, diced	0.46	0.6	1.2	1.0	1.7	0.2	1.0	3(CK)	2.5
	219	7.7	4 beets, 2" diam. or $1\frac{1}{3}$ cups, sliced	1.00	1.4	2.7	2.1	3.7	0.4	2.2	7(CK)	5.5

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Biscuit, baking powder		1.0		0.77	0.8	0.8	0.6	0.3	0.6	0.2	—	0.4
		3.5	$5\frac{1}{2}$ small biscuits	2.70	3.0	2.7	2.2	1.1	2.2	0.5		1.3
	37	1.3	2 small biscuits	1.00	1.1	1.0	0.8	0.4	0.8	0.2		0.5
Blackberries		1.0		0.18	0.1	0.4	0.2	0.5	0.9	+	1	
		3.5	$\frac{5}{8}$ cup	0.62	0.5	1.4	0.7	1.8	3.0		3	
	161	5.7	1 cup or 50 berries 1″ long	1.00	0.8	2.3	1.2	2.9	4.9		5	
Blueberries		1.0		0.19	0.1	0.3	0.1	0.5	0.1		2	0.1
		3.5	$\frac{3}{4}$ cup	0.68	0.2	1.1	0.5	1.8	0.3		8	0.3
	147	5.2	1 cup	1.00	0.4	1.6	0.7	2.7	0.4		11	0.4
Bluefish		1.0		0.25	2.2	0.3	1.5	0.6	—	+	—	+
		3.5	1 piece, 3″x$2\frac{3}{4}$″x$\frac{7}{8}$″	0.88	7.8	0.9	5.1	2.2				
	113	4.0	1 piece, 3″x$2\frac{3}{4}$″x1″	1.00	8.8	1.1	6.0	2.5				
Bologna sausage		1.0		0.62	2.1	—	0.4	1.6	+	+	—	+
		3.5	1 piece, $2\frac{1}{8}$″ diam., $1\frac{1}{6}$″ thick	2.34	7.5	0.1	1.4	5.6				
	43	1.5	1 piece, $2\frac{1}{8}$″ diam., $\frac{1}{2}$″ thick	1.00	3.2	—	0.6	2.4				
Bran, prepared		1.0		0.44	1.5	1.4	5.8	9.6	—	4.5	—	+
		3.5	$1\frac{1}{2}$ cups	1.53	5.3	4.9	20.3	33.6		15.8		
	65	2.3	1 cup	1.00	3.5	3.3	13.2	22.1		10.4		

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread, Boston brown		1.0		0.64	0.6	1.6	1.2	1.7	0.3	2.4	—	0.4
		3.5	2 slices, 3″ diam., $\frac{7}{8}$″ thick	2.26	2.2	5.6	4.2	6.0	0.9	8.5		1.4
	44	1.6	1 slice, 3″ diam., $\frac{3}{4}$″ thick	1.00	1.0	2.4	1.9	2.6	0.4	3.9		0.6
Bread, corn		1.0		0.08	0.8	0.7	0.7	0.4	1.4	1.6	—	0.7
		3.5	$2\frac{2}{3}$ slices, 2″x2″x1″	2.75	2.6	2.4	2.3	1.4	4.8	5.6		2.4
	36	1.3	1 slice, 2″x2″x1″	1.00	9.6	8.7	8.4	5.1	1.8	2.1		0.9
Bread, rye		1.0	1 slice, $3\frac{1}{2}$″x4″x$\frac{1}{2}$″	0.71	1.0	0.3	1.0	0.9	+	3.1	—	+
		3.5	$3\frac{1}{3}$ slices, $3\frac{1}{2}$″x4″x$\frac{1}{2}$″	2.52	3.6	1.0	3.4	3.2		10.9		
	40	1.4	$1\frac{1}{3}$ slices, $3\frac{1}{2}$″x4″x$\frac{1}{2}$″	1.00	1.4	0.4	1.3	1.3		4.4		
Bread, white (with milk)		1.0		0.79	1.0	0.8	0.6	0.5	—	—	—	+
		3.5	5 slices, 3″x$3\frac{1}{2}$″x$\frac{1}{2}$″	2.80	3.6	2.7	2.2	1.6		0.1		
	36	1.3	2 slices, 3″x$3\frac{1}{2}$″x$\frac{1}{2}$″	1.00	1.4	1.0	0.8	0.6		—		
Bread, white (with water)		1.0		0.73	1.1	0.4	0.6	0.5	—	—	—	—
		3.5	5 slices, 3″x$3\frac{1}{2}$″x$\frac{1}{2}$″	2.59	3.6	1.2	2.1	1.8				
	39	1.4	2 slices, 3″x$3\frac{1}{2}$″x$\frac{1}{2}$″	1.00	1.4	0.5	0.8	0.7				
Bread, white, raisin		1.0		0.83	0.8	0.7	0.6	0.4	0.3	0.5	—	0.3
		3.5	3 slices, $3\frac{3}{4}$″x$3\frac{1}{2}$″x$\frac{1}{2}$″	2.92	2.6	2.3	2.0	1.5	1.2	1.8		0.9
	33	1.2	1 slice, $3\frac{3}{4}$″x$3\frac{1}{2}$″x$\frac{1}{2}$″	1.00	0.9	0.8	0.7	0.5	0.4	0.6		0.3

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Bread,		1.0		0.74	1.0	0.5	1.0	1.0		2.2	—	+
whole wheat,		3.5	5 slices, $3''x3\frac{1}{2}''x\frac{1}{2}''$	2.60	3.6	1.7	3.5	3.4		7.7		
50 per cent	39	1.4	2 slices, $3''x3\frac{1}{2}''x\frac{1}{2}''$	1.00	1.4	0.7	1.4	1.2		3.0		
Bread,		1.0	1 slice, $3''x3\frac{3}{4}''x\frac{1}{2}''$	0.81	1.3	0.9	1.3	1.0	—	4.5	—	0.6
whole wheat		3.5	$3\frac{1}{2}$ slices, $3''x3\frac{3}{4}''x\frac{1}{2}''$	2.87	4.4	3.2	4.4	3.4	0.1	15.8		2.0
(with milk)	35	1.2	$1\frac{1}{3}$ slices, $3''x3\frac{3}{4}''x\frac{1}{2}''$	1.00	1.5	1.1	1.5	1.2	—	5.4		0.7
Bread,		1.0	1 slice, $3''x3\frac{3}{4}''x\frac{1}{2}''$	0.70	1.1	0.6	1.0	0.9	—	4.4	—	+
whole wheat		3.5	$3\frac{1}{2}$ slices, $3''x3\frac{3}{4}''x\frac{1}{2}''$	2.49	3.6	2.2	3.5	3.2		15.4		
(with water)	41	1.4	$1\frac{1}{2}$ slices, $3''x3\frac{3}{4}''x\frac{1}{2}''$	1.00	1.6	0.9	1.4	1.3		6.1		
Bread,		1.0		0.77	0.8	0.7	1.0	1.1	0.4	4.1	—	1.1
whole wheat,		3.5	$2\frac{2}{3}$ slices, $3\frac{3}{4}''x3\frac{1}{8}''x\frac{1}{2}''$	2.69	3.0	2.4	3.5	3.8	1.4	14.3		3.8
raisin	37	1.3	1 slice, $3\frac{3}{4}''x3\frac{1}{8}''x\frac{1}{2}''$	1.00	1.1	0.9	1.3	1.4	0.5	5.3		1.4
Broccoli		1.0		0.10	0.4	1.7	0.4	0.8	9.9	1.1(R)*	3(R)	2.0
		3.5	$\frac{7}{8}$ cup, steamed	0.37	1.3	6.1	1.5	2.8	35.0	4.0(R)*	9(R)	7.0
	270	9.5	$2\frac{1}{3}$ cups, steamed	1.00	3.6	16.4	4.2	7.4	94.2	10.8(R)*	24(R)	18.9
Brussels		1.0		0.16	0.5	0.3	0.8	0.7	1.0	+	8(R)	+
sprouts		3.5	7 sprouts, $1\frac{1}{2}''$ diam.	0.58	1.7	1.2	2.7	2.3	3.3		28(R)	
	173	6.1	12 sprouts, $1\frac{1}{2}''$ diam.	1.00	3.1	2.0	4.8	4.2	5.8		48(R)	

* 50 per cent lost in cooking 15 minutes.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Buns,		1.0		0.96	1.1	0.2	0.5	0.4	—		—	—
cinnamon		3.5		3.39	3.9	0.7	1.8	1.4				
	30	1.0	1 bun, $2\frac{3}{4}''$x$2\frac{1}{2}''$x$1\frac{1}{2}''$	1.00	1.1	0.2	0.5	0.4				
Butter		1.0		2.18	0.1	0.2	0.1	0.1	10.3	—	—	—
		3.5	$\frac{1}{2}$ cup (scant)	7.69	0.4	0.7	0.4	0.4	36.1			
	13	0.5	1 tbsp.	1.00	0.1	0.1	0.1	0.1	5.1			
	227	8.0	1 cup	17.44	0.9	1.6	0.9	1.0	82.0			
	7	0.3	1 square, $1\frac{1}{4}''$x$1\frac{1}{4}''$x$\frac{1}{4}''$	0.50	—	—	—	—	2.5			
Buttermilk		1.0		0.10	0.4	1.3	0.6	0.1	—	0.3	—	0.5
		3.5	$\frac{1}{2}$ cup (scant)	0.35	1.4	4.6	2.2	0.6		1.1	2(R)	1.6
	283	10.1	$1\frac{1}{8}$ cups	1.00	4.1	12.8	6.2	1.4		3.1	4(R)	4.5
	241	8.5	1 cup	0.88	3.5	11.3	5.4	1.2		2.7	4(R)	3.9
Cabbage,		1.0		0.05	0.2	0.6	0.3	0.6	5.7	0.7	7(R)	0.4
Chinese		3.5	$\frac{7}{8}$ cup, shredded	0.16	0.6	2.2	1.2	2.0	20.0	2.5	25(R)	1.3
	621	21.9	$\frac{2}{3}$ med. head or $2\frac{3}{4}$ cups, cooked	1.00	3.5	13.8	7.5	12.4	124.2	15.5	155(R)	7.8
Cabbage,		1.0		0.09	0.2	0.6	0.2	0.2	0.2	1.4	8(R)*	0.7
new, partly		3.5	$1\frac{1}{8}$ cups, chopped	0.32	0.6	2.0	0.6	0.8	0.6	5.0	28(R)*	2.5
green	318	11.2	$3\frac{1}{2}$ cups, chopped	1.00	2.0	6.2	2.4	2.7	1.9	15.9	88(R)*	8.0
	64	2.3	$\frac{3}{4}$ cup, shredded	0.20	0.4	1.2	0.4	0.5	0.4	3.2	18(R)*	1.6

* Largely destroyed in cooking.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Cake,		1.0		1.12	0.7	0.5	0.5	0.5	2.7	0.4		0.5
two egg,		3.5	1 piece, $4\frac{1}{4}''$x$5''$x$1''$	4.38	2.6	1.8	1.8	1.8	9.6	1.3		1.8
plain	23	0.8	1 piece, $2''$x$2\frac{1}{4}''$x$1''$	1.00	0.6	0.4	0.4	0.4	2.2	0.3		0.4
Cantaloupe		1.0		0.08	0.1	0.2	0.1	0.2	1.2	0.6	5	
		3.5	$\frac{1}{2}$ cup, balls, $\frac{5}{8}''$ diam.	0.27	0.2	0.7	0.3	0.6	4.3	2.0	18	
	365 (769 A.P.)	12.9	1 melon, $5''$ diam.	1.00	0.9	2.7	1.3	2.8	15.5	7.3	62	
Carrots,		1.0		0.13	0.1	0.6	0.3	0.4	8.8	1.4	1(R)*	0.7
fresh		3.5	$\frac{3}{4}$ cup, $\frac{1}{2}''$ cubes	0.45	0.4	2.0	0.8	1.2	31.0	5.0	4(R)*	2.5
	221	7.8	$1\frac{2}{3}$ cups, $\frac{1}{2}''$ cubes	1.00	1.0	4.4	2.1	2.7	68.5	11.1	7(R)*	5.6
Carrots,		1.0		0.08	0.1	0.4	0.1	0.6	12.9	0.5		0.2
strained,	128	4.5	$\frac{1}{2}$ cup	0.35	0.3	1.6	0.5	2.8	58.1	2.3		0.7
canned	15	0.5	1 tbsp.	0.04	—	0.2	0.1	0.3	6.8	0.3		0.1
Cashew		1.0		1.71	2.2	0.6	3.1		+	+	—	
nuts		3.5	$\frac{3}{4}$ cup	6.05	7.6	2.1	10.9					
	17	0.6	4–5 nuts	1.00	1.3	0.3	1.8					
Cauliflower		1.0		0.09	0.2	1.5	0.4	0.5	0.1	1.6	14†	0.9
		3.5	1 cup, chopped, raw	0.31	0.8	5.3	1.4	1.9	0.5	5.5	50†	3.0
	328	11.6	1 small head, $4\frac{1}{2}''$ diam.	1.00	2.8	17.4	4.5	6.2	1.6	17.0	161†	9.9

* 30 per cent lost in cooking.

† Buds.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Celery, bleached, stems		1.0		0.06	0.2	1.0	0.3	0.4	—	++	2(R)	
		3.5	$\frac{3}{4}$ cup, $\frac{1}{4}''$ pieces	0.20	0.5	3.4	1.1	1.2	0.2		5(R)	
	495	17.5	4 cups, $\frac{1}{4}''$ pieces	1.00	2.6	17.0	5.4	6.1	0.7		25(R)	
Chard		1.0		0.07	0.2	1.2	0.3	1.8	47.7	+		+
		3.5	$\frac{3}{8}$ cup, steamed	0.25	0.6	4.3	1.1	6.2	172.0			
	400	14.1	$1\frac{1}{3}$ cups, steamed	1.00	2.4	17.4	4.5	24.7	688.0			
Cheese, American		1.0		1.25	3.3	11.5	4.5	0.7	7.1	+	—	2.9
		3.5	4 slices, $3\frac{1}{2}''$x$3\frac{1}{4}''$x$\frac{1}{8}''$	4.40	11.5	40.5	15.9	2.6	25.0			10.0
	23	0.8	$1\frac{1}{8}''$ cube	1.00	2.6	9.2	3.6	0.6	5.8			2.3
	8	0.3	1 tbsp. grated, fresh	0.35	0.9	3.1	1.2	0.2	2.0			0.8
Cheese, American, dry	4	0.2	1 tbsp. grated	0.20	0.5	1.8	0.7	0.1	1.2	+	—	0.5
Cheese, Camembert		1.0		0.79	2.4	8.2	3.2	0.5	+	+	—	+
		3.5		2.79	8.4	29.6	11.3	1.8				
	36	1.3	$1\frac{3}{4}''$ sector, 1″ thick, $4\frac{1}{2}''$ diam.	1.00	3.0	10.6	4.1	0.7				
	45	1.6	$2\frac{1}{4}''$ sector, 1″ thick, $4\frac{1}{2}''$ diam.	1.26	3.8	13.3	5.1	0.8				
Cheese, cottage (skim)		1.0		0.31	2.4	1.0	1.7		0.2	+	—	+
		3.5	$5\frac{1}{2}$ tbsp.	1.10	8.4	3.6	6.0		0.8			
	91	3.2	5 tbsp.	1.00	7.6	3.3	5.4		0.7			

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Cheese, Parmesan		1.0		1.07	4.8	16.7	6.4	1.1	3.5	0.4	−	+
		3.5	$1\frac{1}{4}$ cups	3.78	16.8	59.0	22.6	3.8	12.5	1.5		
	27	0.9	$\frac{3}{8}$ cup	1.00	4.4	15.6	6.0	1.0	3.3	0.4		
Cheese, Roquefort		1.0		1.03	2.6	8.9	3.4	0.6	+	+	−	+
		3.5		3.63	9.0	31.6	12.1	2.0				
	28	1.0	1 piece, $2''\times1''\times\frac{3}{4}''$	1.00	2.5	8.7	3.3	0.6				
	42	1.5	$1\frac{1}{4}''$ sector, $1''$ thick, $6\frac{1}{2}''$ diam.	1.50	3.9	13.3	5.1	0.9				
Cheese, soft cream		1.0		1.09	1.3	4.5	1.7	0.3	9.9	0.3	−	0.7
		3.5	$1\frac{1}{6}$ packages	3.85	4.5	15.8	6.0	1.0	35.0	1.0		2.3
	26	0.9	2 tbsp.	1.00	1.2	4.1	1.6	0.3	9.1	0.3		0.6
	85	3.0	1 package, $2\frac{3}{4}''\times2\frac{1}{8}''\times\frac{3}{4}''$	3.28	3.8	13.4	5.2	0.9	29.7	0.9		2.0
Cheese, Swiss		1.0		1.22	3.1	13.4	5.2	0.7	+	+	−	+
		3.5		4.30	11.0	47.2	18.5	2.4				
	23	0.8	1 slice, $4\frac{1}{2}''\times3\frac{1}{2}''\times\frac{1}{8}''$	1.00	2.6	11.0	4.3	0.6				
Cherries, canned		1.0		0.25	0.1	0.2	0.1	0.1	0.8	+	2	+
		3.5	6 cherries, $2\frac{1}{2}$ tbsp. juice	0.90	0.4	0.5	0.4	0.5	2.8		6	
	112	3.9	7 cherries, 3 tbsp. juice	1.00	0.5	0.6	0.5	0.5	3.2		7	

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Cherries, stoned		1.0		0.22	0.1	0.2	0.2	0.2	1.3	+	3	
		3.5	15 cherries	0.78	0.4	0.8	0.7	0.8	4.5		10	
	128 (134 A. P.)	4.5	20 cherries, $\frac{7}{8}''$ diam.	1.00	0.5	1.1	0.9	1.0	5.8		13	
Chestnuts, Italian, shelled		1.0		0.69	0.7	0.4	0.6	0.4		3.1		+
		3.5	17 nuts	2.42	2.5	1.5	2.1	1.4		11.0		
	41	1.5	7 nuts	1.00	1.0	0.6	0.9	0.6		4.5		
Chicken, lean meat of broiler		1.0		0.31	2.4	0.2	1.5	1.8		4.3*	—	+
		3.5	$\frac{1}{2}$ med. broiler	1.09	8.6	0.6	5.3	6.4		15.0*		
	93	3.3	3 slices, $3\frac{1}{2}''$x$2\frac{1}{2}''$x$\frac{1}{4}''$	1.00	8.0	0.5	4.9	6.3		13.9*		
Chicory, *see* Escarole												
Chocolate cake, loaf		1.0		1.11	0.8	0.6	0.7	0.6	2.0	0.3		0.6
		3.5	1 piece, $2\frac{1}{2}''$x$4''$x$2\frac{1}{4}''$	3.89	2.7	2.0	2.3	2.0	7.0	1.1		2.0
	26	0.9	1 piece, $2\frac{1}{2}''$x$2\frac{1}{2}''$x$\frac{7}{8}''$	1.00	0.7	0.5	0.6	0.5	1.8	0.3		0.5
Chocolate, milk, sweet	18	0.6	1 piece, $2\frac{1}{4}''$x$1''$x$\frac{1}{8}''$	1.00								

* Light meat. For dark meat, allow twice as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Chocolate, milk, sweet, with almonds	17	0.6	1 piece, $2\frac{1}{4}''$x$2\frac{1}{4}''$x$\frac{1}{8}''$	1.00								
Chocolate nut caramels	20	0.7	1 piece, $1''$x$1''$x$\frac{4}{5}''$	1.00								
Chocolate, unsweetened		1.0	1 square	1.73	1.5	1.1	2.9	1.5				
		3.5	$3\frac{1}{2}$ squares	6.11	5.2	4.0	10.3	5.4				
	16	0.6	$\frac{2}{3}$ of 1 square	1.00	0.8	0.7	1.7	0.9				
	5	0.2	1 tbsp. grated	0.29	0.2	0.2	0.5	0.3				
Chocolate wafers, double with sugar filling		1.0		1.40	0.6							
		3.5	8 wafers, 2″ diam.	4.94	2.0							
	20	0.7	$1\frac{2}{3}$ wafers, 2″ diam.	1.00	0.4							
Clams, long (soft shells)		1.0		0.15	1.0	1.5	0.7	2.3	0.1			—
		3.5	10 clams	0.51	3.4	5.4	2.4	8.2	0.2			0.3
	195	6.9	20 clams	1.00	6.7	10.4	4.6	16.0	0.4			0.5
Clams, round		1.0		0.13	0.7	1.3	0.8	2.5	0.1			—
		3.5	6 clams or $\frac{1}{3}$ cup	0.46	2.5	4.6	2.6	8.8	0.2			0.3
	216	7.6	12 clams or $\frac{2}{3}$ cup	1.00	5.6	9.9	5.7	19.4	0.4			0.5

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Cocoa, powder		1.0		1.41	2.5	1.4	4.6	1.5				
		3.5	¾ cup	4.97	8.6	4.9	16.1	5.4				
	20	0.7	2½ tbsp.	1.00	1.7	1.0	3.3	1.1				
	8	0.3	1 tbsp.	0.40	0.7	0.4	1.3	0.4				
Coconut, custard pie		1.0		0.59	0.6	1.0	0.6	0.5	1.6	0.5		0.9
		3.5		2.04	2.3	3.5	2.3	1.9	5.5	1.9		3.1
	49	1.7	1″ sector, 9″ diam.	1.00	1.1	1.7	1.1	0.9	2.7	0.9		1.5
	231	8.1	4½″ sector, 9″ diam.	4.73	5.4	8.1	5.3	4.5	12.7	4.3		7.1
Cod liver oil		1.0		2.55	—	—	—	—	122.0*	—	—	—
		3.5	½ cup	9.00					430.0*			
	11	0.4	1 tbsp.	1.00					47.8*			
Cod roe		1.0		0.57	2.3	0.2	3.3	0.9	8.5	4.0		+
		3.5		2.02	8.2	0.7	11.5	3.2	30.0	14.0		
	50	1.7		1.00	4.1	0.3	5.7	1.6	14.9	6.9		
Cod steak		1.0		0.22	2.1	0.1	1.2	0.2	—	0.6	—	+
		3.5	1 piece, 3¾″x2½″x¾″	0.79	7.5	0.4	4.2	0.7		2.0		
	127 (138 A. P.)	4.5	1 piece, 3¾″x2½″x1″	1.00	9.5	0.6	5.4	0.9		2.5		

* U.S.P. Standard 1936. For various brands, see container.

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Collards		1.0		0.14	0.5	2.5	0.5	1.1	12.8	2.8	7(CK)	1.4
		3.5	½ cup, steamed	0.49	1.7	8.7	1.7	3.8	45.0	10.0	23(CK)	5.0
	204	7.2	1 cup, steamed	1.00	3.4	17.9	3.4	7.8	91.8	20.4	47(CK)	10.2
Corn, canned		1.0		0.28	0.3	0.1	0.6	0.3				
		3.5	⅖ cup	1.00	1.2	0.3	2.3	0.9				
	255	9.0	1 cup	2.60	3.1	0.7	5.9	2.3				
Corn, fresh		1.0		0.29	0.4	0.1	0.7	0.3	+	+	3(R)	+
		3.5		1.03	1.3	0.3	2.5	0.9			10(R)	
	97 (255 A. P.)	3.4	½ cup or 2 ears 6″ long	1.00	1.3	0.3	2.3	0.9			10(R)	
Cornflakes		1.0		1.09	0.9	0.2	0.7	1.5			—	
		3.5	3 cups	3.83	3.3	0.6	2.6	5.4				
	26	0.9	¾ cup	1.00	0.9	0.2	0.7	1.4				
Cornmeal, yellow, whole grain, cooked	170	6.0	⅔ cup	1.00	1.0	0.2	1.0	0.5	1.7*	3.1	—	0.5
Cornmeal, yellow, whole grain, uncooked		1.0		1.00	1.0	0.2	1.0	0.5	1.7*	3.6	—	0.5
		3.5	¾ cup (scant)	3.52	3.7	0.8	3.4	1.8	6.0*	12.5		1.7
	28	1.0	3 tbsp.	1.00	1.0	0.2	1.0	0.5	1.7*	3.6		0.5
	142	5.0	1 cup	5.04	5.0	1.0	4.9	3.0	8.5*	17.7		2.3

* None in white.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Corn syrup (dark)		1.0		0.96	—	0.7	—	7.3	—	—	—	—
		3.5	¼ cup	3.40		2.6	0.2	25.6				
	29	1.0	1⅓ tbsp.	1.00		0.7	—	7.5				
Corn syrup (light)		1.0		0.96	—	0.1	—	0.8	—	—	—	—
		3.5	¼ cup	3.40		0.4	0.2	2.8				
	29	1.0	1⅓ tbsp.	1.00		0.1	—	0.8				
Cottonseed oil		1.0		2.55	—	—	—	—	—	—	—	—
		3.5	½ cup	9.00								
	11	0.4	1 tbsp.	1.00								
Crabmeat, canned		1.0		0.23	1.8	0.2	1.2	0.5		+	—	+
		3.5	⅝ cup	0.80	6.3	0.7	4.1	1.8				
	126	4.4	¾ cup	1.00	8.0	0.9	5.2	2.3				
Crackers, graham		1.0		1.19	1.1	0.3	1.3	1.1			—	
		3.5	10½ crackers, 2½″x2¾″x¼″	4.20	4.0	0.9	4.6	3.8				
	24	0.8	2½ crackers	1.00	1.0	0.2	1.1	0.9				
	10	0.4	1 cracker	0.40	0.4	0.1	0.5	0.4				
Crackers, oysters		1.0		1.20	1.3	0.3	0.7	0.8			—	
		3.5	100 crackers, 1″ diam.	4.22	4.5	1.2	2.4	2.8				
	24	0.8	24 crackers	1.00	1.1	0.3	0.6	0.7				

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Crackers, soda		1.0		1.17	1.1	0.3	0.7	0.9			—	
		3.5	16 crackers, $2\frac{3}{4}''$x$2\frac{1}{2}''$	4.14	3.9	1.0	2.3	3.0				
	24	0.9	4 crackers	1.00	1.0	0.3	0.6	0.7				
	6	0.2	1 cracker	0.25	0.3	0.1	0.2	0.2				
Cranberries, fresh		1.0		0.13	—	0.2	0.1	0.3	0.1	—	4	
		3.5	1 cup	0.47	0.2	0.5	0.2	0.9	0.2		13	
	213	7.5	2 cups	1.00	0.3	1.1	0.5	1.9	0.4		27	
Cream, thin (18.5 per cent fat)		1.0		0.55	0.3	1.2	0.6	0.1	2.1			
		3.5	$\frac{3}{8}$ cup	1.95	1.0	4.2	2.0	0.4	7.4			
	51	1.8	$\frac{1}{4}$ cup (scant)	1.00	0.5	2.2	1.0	0.2	3.8			
	16	0.6	1 tbsp.	0.30	0.1	0.7	0.3	0.1	1.2			
	227	8.0	1 cup	4.40	2.2	9.6	4.4	0.9	16.8			
Cream, thick (40 per cent fat)		1.0		1.08	0.3	1.1	0.4	0.1	4.5			
		3.5	$\frac{3}{8}$ cup	3.81	0.9	3.7	1.5	0.4	15.7			
	26	0.9	$1\frac{2}{3}$ tbsp.	1.00	0.2	0.9	0.4	0.1	4.1			
	16	0.6	1 tbsp. or $1\frac{3}{4}$ tbsp., whipped	0.60	0.1	0.5	0.3	0.1	2.5			
	221	7.8	1 cup	8.42	1.9	7.3	3.8	0.8	34.7			
Cucumbers		1.0		0.04	0.1	0.1	0.1	0.2	0.1	+	4	
		3.5	14 slices, $\frac{1}{8}''$ thick, $1\frac{1}{2}''$ to $2''$ diam.	0.14	0.3	0.5	0.5	0.6	0.4		13	
	730	25.8	2 cucumbers, 10″ long	1.00	2.0	3.2	3.5	4.8	2.1		92	

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight: Gms.	Weight: Oz.	Approximate Measure	Shares: Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Currants, fresh		1.0		0.17	0.2	0.3	0.2	0.4			5*	
		3.5	¾ cup	0.61	0.6	1.1	0.9	1.3			17*	
	165	5.8	1½ cups	1.00	1.1	1.9	1.4	2.3			27*	
Dandelion greens		1.0		0.15	0.3	1.0	0.5	1.7	70.9	++	2(R)	++
		3.5	1⅓ cups, steamed	0.52	1.1	3.6	1.6	6.0	250.0		5(R)	
	191	6.7	2½ cups, steamed	1.00	2.1	7.0	2.7	11.7	477.5		23(R)	
Dates, dried, stoned		1.0		1.00	0.2	0.9	0.4	2.0	0.3	1.1	—	
		3.5	14 dates	3.47	0.8	3.0	1.3	7.1	1.1	4.0		
	29 (32 A. P.)	1.0	4 dates	1.00	0.2	0.9	0.4	2.1	0.3	1.2		
Egg plant		1.0		0.08	0.1	0.1	0.2	0.3	0.1	1.2	1	
		3.5	2 slices, 4″ diam., ⅜″ thick	0.28	0.5	0.5	0.7	1.0	0.5	4.0	4	
	358	12.6	6 slices, 4″ diam., ½″ thick	1.00	1.7	1.7	2.5	3.6	1.8	14.4	13	
Eggs		1.0		0.42	1.5	0.8	1.4	1.7	5.5	1.6	—	2.0
		3.5	2 eggs	1.48	5.4	2.7	5.0	5.8	19.8	5.6		7.2
	68	2.4	1⅓ eggs	1.00	3.6	1.8	3.4	3.9	13.4	3.9		4.9
Eggs, A. P.	53	1.9	1 egg	0.70	2.5	1.3	2.4	2.7	9.4	2.7	—	3.4

* Red. Black 10 times as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Egg white		1.0		0.14	1.4	0.2	0.1	0.1	—	—	—	1.4
		3.5	$3\frac{1}{2}$ whites	0.51	4.9	0.6	0.3	0.2				5.0
	196	6.9	7 whites	1.00	9.7	1.1	0.7	0.4				9.8
	28	1.0	1 white	0.14	1.4	0.2	0.1	0.1				1.4
Egg yolk		1.0		1.03	1.8	1.6	3.8	4.9	10.2	5.0	—	3.3
		3.5	$6\frac{1}{2}$ yolks	3.63	6.3	5.6	13.3	17.2	35.8	17.5		11.5
	28	1.0	2 yolks	1.00	1.7	1.6	3.7	4.7	10.0	4.9		3.2
	16	0.6	1 yolk	0.56	1.0	0.9	2.2	2.6	5.7	2.8		1.8
Endive		1.0		0.07	0.2	1.3	0.3	0.7	+	++	3	
		3.5	2 stalks, $5\frac{3}{4}''$ long	0.24	0.6	4.5	0.9	2.5			10	
	417	14.7	7 stalks, $5\frac{3}{4}''$ long	1.00	2.6	18.7	3.7	10.0			42	
Escarole		1.0		0.06	0.2	0.4	0.2	1.0	60.0	+	2	1.4
		3.5	4 leaves	0.21	0.6	1.2	0.7	3.0	210.0		6	4.8
	483	17.0	21 leaves	1.00	3.1	5.6	3.1	14.3	1014.0		27	23.0
Farina, dark, uncooked		1.0		1.00	1.2	0.6	2.7	2.8	—	4.3	—	1.2
		3.5	$\frac{3}{4}$ cup	3.62	4.4	2.0	9.6	10.0	0.2	15.0		4.0
	28	1.0	3 tbsp.	1.00	1.2	0.6	2.7	2.8	—	4.2		1.1
	170	6.0	1 cup	6.15	7.6	3.4	16.4	17.2	0.3	28.5		6.8
Farina, dark, cooked	170	6.0	$\frac{3}{4}$ cup	1.00	1.2	0.6	2.7	2.8	—	3.6	—	1.1

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Farina, dark, with wheat germ		1.0		1.03	1.6	0.5	2.6	2.3		17.0		
		3.5	$\frac{2}{3}$ cup	3.63	5.7	1.7	9.1	8.0		60.0		
	28	1.0	3 tbsp.	1.00	1.6	0.5	2.5	2.2		16.5		
Farina, light, uncooked		1.0		1.03	1.2	0.3	0.8	0.4	—	0.1	—	—
		3.5	$\frac{5}{8}$ cup	3.62	4.4	0.9	2.8	1.6		0.5		
	28	1.0	3 tbsp.	1.00	1.2	0.3	0.8	0.4		0.1		
	170	6.0	1 cup	6.15	7.5	1.6	4.9	2.7		0.9		
Fig bars		1.0		1.01	0.5							
		3.5	$3\frac{1}{2}$ bars	3.57	1.8							
	28	1.0	1 bar	1.00	0.5							
Figs, dried		1.0		0.90	0.5	2.0	0.8	1.6	0.2	1.0	—	0.6
		3.5	6 medium	3.17	1.7	7.0	2.6	5.8	0.7	3.5		2.0
	32	1.1	2 medium	1.00	0.5	2.2	0.8	1.8	0.2	1.1		0.7
Figs, fresh		1.0		0.25	0.2	0.7	0.2	0.5	0.2	1.0	—	
		3.5	$2\frac{1}{2}$ small, $1\frac{1}{2}''$ diam.	0.88	0.6	2.3	0.8	1.6	0.6	3.5	2	
	114	4.0	3 small, $1\frac{1}{2}''$ diam.	1.00	0.6	2.6	0.9	1.8	0.6	4.0	3	
Fish, white, fried in butter and crumbs (average of 15 varieties)		1.0		0.59	2.2	0.8*	1.5	0.6		+	—	+
		3.5		2.09	7.7	3.1	5.3	2.2				
	48	1.7		1.00	3.7	1.4	2.5	1.1				

* Average of 5 varieties.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Fish, white,		1.0		0.29	2.5	0.6*	1.5	0.4		+	—	+
steamed	99	3.5	1 piece, $3\frac{3}{4}''$x$2\frac{1}{4}''$x$\frac{3}{4}''$	1.00	8.9	2.2	5.2	1.4				
(average of 15 varieties)												
Flounder,		1.0		0.18	1.6	0.4	1.0	0.4		+	—	+
"sole"		3.5	1 piece, $2\frac{1}{2}''$x$2\frac{1}{2}''$x1″	0.62	5.7	1.6	3.7	1.4				
	161	5.7	1 piece, 4″x$2\frac{1}{2}''$x1″	1.00	9.2	2.5	6.0	2.3				
Flour,		1.0		1.00	0.8	0.2	1.9	0.9		3.1	—	
rye		3.5	$\frac{3}{4}$ cup	3.50	2.7	0.8	6.6	3.0		11.0		
	29	1.0	3 tbsp.	1.00	0.8	0.2	1.9	0.9		3.1		
	9	0.3	1 tbsp.	0.33	0.3	0.1	0.6	0.3		1.0		
	142	5.0	1 cup	4.96	3.9	1.1	9.2	4.3		15.6		
Flour,		1.0		1.00	1.3	0.2	0.7	0.6	—	0.1	—	—
wheat,		3.5	$\frac{7}{8}$ cup, sifted	3.53	4.5	0.7	2.4	2.0		0.5		
white	28	1.0	3 tbsp., unsifted	1.00	1.3	0.2	0.7	0.6		0.1		
	7	0.3	1 tbsp., sifted	0.25	0.3	0.1	0.2	0.1		—		
	112	3.9	1 cup, sifted	3.95	5.1	0.8	2.7	2.2		0.6		
Flour,		1.0		1.00	1.5	0.4	2.0	2.0	—	4.3	—	1.2
whole		3.5	$\frac{3}{4}$ cup (scant)	3.59	5.3	1.5	6.9	7.4	0.2	15.0		4.0
wheat	28	1.0	3 tbsp.	1.00	1.5	0.4	2.0	2.0	—	4.2		1.1
	9	0.3	1 tbsp.	0.34	0.5	0.1	0.6	0.7	—	1.4		0.4
	142	5.0	1 cup	5.10	7.5	2.2	9.8	10.2	0.2	21.3		5.7

* Average of 6 varieties.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Frankfort sausages		1.0		0.71	2.2	0.1	1.4	1.4	+	+	—	+
		3.5	2½ sausages	2.48	7.8	0.5	5.1	5.0				
	40	1.4	1 sausage	1.00	3.1	0.2	2.0	2.0				
Fruit cake	26	0.9	1 piece, 1⅞″x1⅞″x⅜″	1.00	0.6							
Fudge, chocolate	26	0.9	1 piece, 1½″x¾″x1″	1.00	0.2							
Gelatin	9	0.3	1 tbsp.	0.33	3.3	—	—	—	—	—	—	—
Ginger ale	314	11.1	1⅓ cups	1.00	—	—	—	—	—	—	—	—
Grapefruit		1.0		0.13	0.1	0.3	0.1	0.2	—	0.6	9*	0.6
		3.5	½ cup, ½″ pieces	0.47	0.3	0.9	0.5	0.6		2.0	38*	2.0
	213 (286 A. P.)	7.5	½ medium	1.00	0.5	1.7	0.8	1.2		4.3	69*	4.3
Grapefruit juice, unsweetened		1.0		0.12	—	0.3	0.1	0.1	—	0.6	9	0.6
		3.5	⅜ cup	0.42	—	1.2	0.5	0.4		2.0	33	2.0
	238	8.3	1 cup	1.00	0.4	2.8	1.1	1.0		4.8	78	4.8
Grape juice		1.0		0.20	—	0.1	0.1	0.2	—	—	—	—
		3.5	½ cup (scant)	0.70	0.1	0.4	0.2	0.7				
	143	5.0	⅔ cup	1.00	0.2	0.7	0.3	0.9				

* Canned, 10 per cent less.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Grapes		1.0		0.22	0.2	0.2	0.2	0.4	0.1	0.6	—	—
		3.5	20 grapes (Malaga size)	0.77	0.5	0.8	0.7	0.6	0.3	2.0	2	
	128	4.5	26 grapes (Malaga size)	1.00	0.7	1.0	1.0	1.9	0.3	2.6	2	
Guavas		1.0		0.22	0.1	0.2	0.1	0.2	0.8	0.8	43	0.5
		3.5		0.78	0.4	0.7	0.4	0.6	2.8	2.1	150	1.8
	156	5.6		1.00	0.5	0.8	0.5	0.8	3.6	3.6	194	2.3
Haddock, fresh		1.0		0.20	2.0	0.2	1.3	0.5	—	+	—	+
		3.5	Section, $1\frac{1}{3}''$ on back, $4''$ wide	0.72	6.9	0.8	4.5	1.8	0.1			
	140	4.9	Section, $1\frac{3}{4}''$ on back, $4''$ wide	1.00	9.6	1.2	6.3	2.5	0.1			
Halibut steak		1.0		0.34	2.1	0.1	1.3	0.5	+	+	—	+
		3.5	1 piece, $3''\text{x}1\frac{3}{4}''\text{x}1''$	1.21	7.4	0.4	4.5	1.9				
	83	2.9	1 piece, $3''\text{x}1\frac{3}{8}''\text{x}1''$	1.00	6.1	0.3	3.8	1.6				
Ham, boiled, lean only		1.0		0.60	2.6	0.2	1.6	1.5	+	++	—	++
		3.5	2 slices, $5''\text{x}5''\text{x}\frac{1}{8}''$	2.13	9.2	0.7	5.5	5.2				
	47	1.7	1 slice, $5''\text{x}5''\text{x}\frac{1}{8}''$	1.00	4.3	0.3	2.6	2.4				
Ham, fat (of boiled ham)		1.0		2.38	0.3	—	2.2	1.2	+	—	—	—
		3.5	$\frac{1}{2}$ cup	8.39	1.1	0.1	7.9	4.4				
	12	0.4	1 tbsp.	1.00	0.1	—	0.9	0.5				

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Ham, smoked, lean		1.0		0.76	2.2	0.3	1.0	0.8		++	—	++
		3.5	3 slices, $4\frac{1}{4}''$x$4''$x$\frac{1}{8}''$	2.66	7.9	1.0	3.4	2.8				
	38	1.3	1 slice, $4\frac{3}{4}''$x$4''$x$\frac{1}{8}''$	1.00	3.0	0.4	1.3	1.1				
Hamburg steak		1.0		0.45	1.7	0.1	1.0	1.0	0.5	0.8	—	1.0
		3.5	1 ball, 2 tbsp. gravy	1.59	6.0	0.5	3.6	3.3	1.9	2.6		3.3
	64	2.2	$\frac{2}{3}$ ball, $1\frac{1}{3}$ tbsp. gravy	1.00	3.8	0.3	2.3	2.1	1.2	1.7		2.1
Herring, fresh		1.0		0.40	2.2	0.3	1.4	0.6	+	+	—	+
		3.5		1.42	7.8	0.9	5.1	2.2				
	71	2.5		1.00	5.5	0.7	3.6	1.5				
Herring, smoked		1.0		0.82	4.8	0.5	2.7	1.1	+	+	—	+
		3.5	Section, $4''$ on back, $2\frac{1}{4}''$ wide	2.90	14.8	1.7	9.6	4.0				
	35	1.2	Section, $1\frac{1}{2}''$ on back, $2\frac{1}{4}''$ wide	1.00	5.1	0.6	3.3	1.5				
Hominy grits, cooked	193	6.8	$\frac{4}{5}$ cup	1.00	0.9	0.2	0.5	0.5			—	
Hominy grits, uncooked		1.0		1.00	0.9	0.2	0.5	0.5			—	
		3.5	$\frac{5}{8}$ cup	3.55	3.3	0.5	1.6	1.8				
	28	1.0	3 tbsp.	1.00	0.9	0.2	0.5	0.5				
	156	5.5	1 cup	5.53	5.1	1.1	2.5	2.8				

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Honey		1.0		0.93	—	0.1	0.1	0.4	—	—	—	—
		3.5	$\frac{1}{4}$ cup	3.26	0.2	0.2	0.4	1.4				
	31	1.1	1 tbsp.	1.00	0.1	0.1	0.1	0.4				
Huckleberries, *see* Blueberries												
Ice cream, commercial, vanilla		1.0		0.62	0.3	0.9	0.4	0.1	1.8	0.1	—	0.3
		3.5	$\frac{1}{2}$ cup	2.19	1.0	3.3	1.5	0.4	6.4	0.4	1	1.1
	46	1.6	$\frac{1}{4}$ cup	1.00	0.4	1.5	0.7	0.2	2.9	0.2	1	0.5
Jelly, fruit		1.0		0.89	—	—	—	—	—	—	—	—
		3.5	$\frac{1}{3}$ cup	3.10								
	32	1.1	$1\frac{3}{4}$ tbsp.	1.00								
Kale		1.0		0.15	0.4	2.4	0.5	1.4	73.4	1.4		2.9
		3.5	$1\frac{1}{8}$ cups, steamed	0.51	1.4	8.5	1.6	5.0	259.0	5.0		10.0
	196	6.9	$2\frac{1}{3}$ cups, steamed	1.00	2.7	16.8	3.2	12.2	507.8	9.8		19.6
Kidney, veal		1.0		0.36	1.9	0.1	1.2	2.3	2.3	2.5	—	11.3
		3.5	$\frac{1}{2}$ cup, cubed	1.25	6.8	0.4	4.1	8.2	8.1	8.8		40.0
	80	2.8	$\frac{3}{8}$ cup, cubed	1.00	5.4	0.3	3.3	6.6	6.4	7.0		32.0
Kohlrabi		1.0		0.10	0.2	1.0	0.3	0.4		0.7	16(R)	
		3.5	$\frac{3}{4}$ cup, $\frac{1}{2}''$ cubes	0.35	0.8	3.3	1.0	1.2		2.5	55(R)	
	277	9.8	2 cups, $\frac{1}{2}''$ cubes	1.00	2.3	9.3	2.8	3.4		6.9	153(R)	

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Lamb chops, broiled		1.0		1.00	2.5	0.2	1.5	1.9	–	+	–	+
		3.5		3.56	6.8	0.6	5.3	6.6				
	28	1.0	1 small chop	1.00	2.5	0.2	1.5	1.9				
	46	1.6	1 chop, lean meat, $2''\times1\frac{1}{2}''\times\frac{3}{4}''$	1.00	4.0	0.3	2.5	3.0				
Lamb, leg, medium fat		1.0		0.64	2.2	0.1	1.3	0.9	–	+	–	+
		3.5	2 slices, $3\frac{3}{8}''\times4\frac{1}{4}''\times\frac{1}{8}''$	2.25	7.7	0.5	4.7	3.0				
	44	1.6	1 slice, $3\frac{1}{4}''\times4\frac{1}{4}''\times\frac{1}{8}''$	1.00	3.4	0.2	2.1	1.3				
Lamb, leg, roasted		1.0		0.55	2.2	0.1	1.4	0.9	–	+	–	+
		3.5	2 slices, $3\frac{1}{2}''\times4\frac{1}{2}''\times\frac{1}{8}''$	1.93	7.9	0.5	4.8	3.2				
	52	1.8	1 slice, $3\frac{1}{2}''\times4\frac{1}{2}''\times\frac{1}{8}''$	1.00	4.1	0.3	2.5	1.7				
Lard		1.0		2.55	–	–	–	–	–	–	–	–
		3.5	$\frac{1}{2}$ cup	9.00								
	11	0.4	1 tbsp. (scant)	1.00								
	227	8.0	1 cup	20.42								
Lemon juice		1.0		0.11	–	0.3	0.1	0.3	–	+	9	+
		3.5	$\frac{1}{2}$ cup (scant)	0.39		1.0	0.2	1.2			33	
	255	9.0	$1\frac{1}{8}$ cups	1.00		2.6	0.6	3.1			84	
	13	0.5	1 tbsp.	0.05		0.2	–	0.2			4	
Lemons, A. P.	324	11.4	3 large	1.00	0.9	2.3	0.5	2.7	–	+	74	+

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Lentils, dried		1.0		1.00	2.9	1.3	2.5	4.9		1.7	—	1.1
		3.5	½ cup	3.49	10.2	4.4	8.7	17.2		6.0		3.8
	29	1.0	2½ tbsp.	1.00	2.9	1.3	2.5	4.9		1.7		1.1
Lettuce, head, bleached (Iceberg)		1.0		0.05	0.1	0.2	0.3	0.3	0.4*	1.1	1	0.4
		3.5	6 large leaves	0.19	0.5	0.7	0.9	1.0	1.3*	3.8	4	1.3
	571	20.2	2 large heads	1.00	2.5	4.4	5.3	5.9	7.2*	20.2	18	7.2
	57	2.0	⅕ large head or 3 large leaves	0.10	0.3	0.4	0.5	0.6	0.7*	2.2	2	0.7
Lettuce, Romaine		1.0		0.05	0.1	0.6	0.3	0.5	34.0	1.1	1	0.7
		3.5	9 leaves, 9″ long	0.19	0.5	2.0	1.2	1.8	120.0	3.8	4	2.5
	571	20.2	2 heads, 9½″ long	1.00	2.7	12.3	6.0	10.1	705.0	21.7	21	14.3
	57	2.0	5 leaves, 9″ long	0.10	0.3	1.1	0.7	1.0	70.5	2.2	2	1.4
Liver, beef		1.0		0.37	2.3	0.1	2.4	4.6	27.8	2.8	+	12.9
		3.5	1 piece, 3″x3″x⅝″	1.29	8.2	0.5	8.3	16.4	98.0	10.0		45.0
	78	2.7	1 piece, 3″x3″x½″	1.00	6.3	0.4	6.5	12.7	75.6	7.8		34.7
	117	4.0	1 piece, 3″x3″x¾″	1.50	10.1	0.6	9.5	18.6	114.7	11.7		52.7
Liver, beef, boiled, ground	59	2.1	½ cup	1.00	6.3	0.4	6.5	12.7	75.6	7.8		34.7

* Outer green leaves at least 30 times as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Liver,		1.0		0.70	3.2	0.1	3.8	2.9	+	+		+
veal, rolled		3.5	1 piece, 5″x3″x$\frac{3}{8}$″	2.47	11.6	0.4	13.1	10.4				
in flour and fried	40	1.4	1 piece, 2″x3″x$\frac{3}{8}$″	1.00	4.7	0.2	5.3	4.2				
Lobster,		1.0		0.33	2.4	0.8	1.8	0.5				
boiled		3.5	$\frac{3}{4}$ cup (scant)	1.15	8.5	2.7	6.4	1.6				
	87	3.1	$\frac{2}{3}$ cup	1.00	7.4	2.3	5.6	1.4				
Loganberries		1.0		0.20	0.1	0.4	0.2	0.8	+	+	+	
		3.5	$\frac{2}{3}$ cup	0.69	0.4	1.5	0.5	2.8				
	144	5.1	1 cup	1.00	0.6	2.2	0.8	4.1				
Macaroni, cooked	163	5.8	$\frac{3}{4}$ cup	1.00	1.5	0.3	0.9	0.7	–	–	–	–
Macaroni,		1.0		1.00	1.5	0.3	0.9	0.7	–	0.1	–	–
uncooked		3.5	1 cup or 10 sticks 9″ long	3.58	5.4	1.0	3.3	2.4		0.5		
	28	1.0	$\frac{1}{4}$ cup, 1″ pieces	1.00	1.5	0.3	0.9	0.7		0.1		
Mackerel,		1.0		0.39	2.1	0.1	1.8	0.5	+	+		+
fresh		3.5	Cross section, $3\frac{1}{2}$″ on back	1.39	7.5	0.5	6.2	1.8				
	72	2.5	Cross section, $2\frac{1}{2}$″ on back	1.00	5.4	0.3	4.5	1.3				

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Mangoes		1.0		0.21	—	—	0.1	0.2	5.7	0.6	+++	++
		3.5		0.73	0.3	0.2	0.4	0.6	20.0	2.0		
	136	4.8		1.00	0.4	0.3	0.5	0.8	27.2	2.7		
Maple syrup		1.0		0.81	—	1.3	0.1	1.7	—	—	—	—
		3.5	¼ cup	2.84		4.7	3.0	6.0				
	35	1.2	1½ tbsp.	1.00		1.6	0.1	2.0				
Mayonnaise dressing		1.0		2.04	0.2	0.2	0.2	0.2	1.0	0.2		0.3
		3.5	½ cup (scant)	7.19	0.6	0.7	0.7	0.7	3.2	0.7		1.1
	14	0.5	1 tbsp.	1.00	0.1	0.1	0.1	0.1	0.5	0.1		0.2
Milk, condensed (sweetened)		1.0		0.94	0.9	3.9	1.5	0.4	+	+	+	+
		3.5	⅓ cup	3.29	3.1	13.0	5.3	1.2				
	30	1.1	1½ tbsp.	1.00	1.0	4.2	1.6	0.4				
	20	0.7	1 tbsp.	0.66	0.6	2.8	1.1	0.3				
	312	11.0	1 cup	10.35	9.9	42.5	16.7	4.1				
Milk, evaporated (unsweetened)		1.0		0.40	0.8	3.9	1.6	0.4	1.2	0.7	+	1.9
		3.5	⅜ cup	1.40	2.7	13.7	5.5	1.4	4.4	2.6		6.7
	71	2.5	4½ tbsp.	1.00	2.0	9.7	4.0	1.0	3.1	1.8		4.8
	227	8.0	1 cup	3.20	6.2	31.1	12.5	3.0	10.0	5.9		15.2
	411	14.5	1 can	5.80	11.4	56.5	22.8	5.8	18.1	10.7		27.6

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Milk, malted		1.0		1.15	1.6	4.4	2.2	1.2	1.3	6.4	+	3.6
		3.5	¾ cup	4.04	5.5	15.5	7.8	4.2	4.5	22.5		12.5
	25	0.9	3 tbsp.	1.00	1.4	4.0	2.0	1.1	1.1	5.6		3.2
	9	0.3	1 tbsp	0.36	0.5	1.4	0.7	0.4	0.4	2.0		1.1
Milk, skimmed		1.0		0.10	0.4	1.5	0.6	0.1	—	0.3	—	0.5
		3.5	½ cup (scant)	0.37	1.4	5.3	2.2	0.6		1.1	2(R)	1.6
	273	9.6	1⅛ cups	1.00	3.7	14.4	6.0	1.4		3.0	4(R)	4.4
	20	0.7	1 tbsp.	0.07	0.3	1.0	0.4	0.1		0.2	—	0.3
	241	8.5	1 cup	0.88	3.3	12.7	5.2	1.2		2.7	4(R)	3.8
	975	34.4	1 quart	3.58	13.3	51.5	21.3	4.9		10.7	15(R)	15.6
Milk, whole, dried		1.0	4 tbsp.	1.44	2.8	11.4	4.6	0.9	3.4*	4.3	3	7.1
		3.5	1 cup	5.08	10.0	40.0	16.1	3.0	12.0*	15.0	11	25.0
	20	0.7	3 tbsp. (scant)	1.00	2.0	7.9	3.2	0.6	2.4*	3.0	2	5.0
Milk, whole, fresh		1.0		0.20	0.4	1.4	0.6	0.1	0.6	0.3	—	0.5
		3.5	⅜ cup	0.69	1.3	5.1	2.1	0.4	2.1	1.1	2(R)†	1.6
	145	5.1	⅝ cup	1.00	1.9	7.4	3.1	0.7	3.0	1.6	2(R)†	2.3
	20	0.7	1 tbsp.	0.14	0.3	1.0	0.4	0.1	0.4	0.2	—	0.3
	244	8.6	1 cup	1.70	3.2	12.6	5.2	1.2	5.1	2.7	4(R)†	3.9
	975	34.4	1 quart	6.75	12.8	50.0	20.6	4.7	20.2	10.8	15(R)†	15.6

* Stored 9 months one-third as much.

† At least 20 per cent lost in pasteurization.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Molasses, cane		1.0		0.81	0.3	3.2	0.2	4.1	—	—	—	—
		3.5	$\frac{1}{3}$ cup	2.87	1.0	11.5	0.7	14.6				
	35	1.2	$1\frac{1}{2}$ tbsp.	1.00	0.3	3.9	0.2	5.1				
	23	0.8	1 tbsp.	0.65	0.2	2.5	0.2	3.3				
	284	10.0	1 cup	8.15	2.7	31.8	1.9	41.4				
Muffins, one egg		1.0		0.78	1.0	1.0	0.7	0.5	1.2	0.3		0.6
		3.5	2 muffins, $2\frac{3}{4}''$ diam.	2.72	3.5	3.5	2.5	1.6	4.1	1.0		2.3
	35	1.2	$\frac{3}{4}$ muffin, $2\frac{3}{4}''$ diam.	1.00	1.3	1.3	1.0	0.6	1.6	0.4		0.8
	47	1.7	1 muffin, $2\frac{3}{4}''$ diam.	1.32	1.7	1.7	1.2	0.8	2.0	0.5		1.1
Muffins, whole wheat		1.0		0.70	0.8	1.4	0.8	1.4	0.3	1.7		0.4
		3.5	$1\frac{3}{4}$ muffin, $2\frac{3}{4}''$ diam.	2.46	3.0	5.0	3.0	5.0	1.1	5.9		1.5
	40	1.4	$\frac{3}{4}$ muffin, $2\frac{3}{4}''$ diam.	1.00	1.2	2.1	1.2	2.0	0.4	2.4		0.6
	53	1.9	1 muffin, $2\frac{3}{4}''$ diam.	1.33	1.6	2.7	1.6	2.7	0.6	3.2		0.8
Mushrooms		1.0		*	*	0.2	0.6	0.4		2.8	2	
		3.5	10 mushrooms, $1\frac{1}{2}''$ diam.			0.7	2.2	1.4		10.0	5	
Muskmelons, *see* Cantaloupes												

* None available.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Mustard greens		1.0		0.09	0.3	2.7	0.4	3.2	0.9	++	++	2.2
		3.5	¾ cup, steamed	0.31	1.0	9.6	1.5	11.2	3.0			7.5
	326	11.5	2½ cups, steamed	1.00	3.3	31.2	4.9	36.5	9.8			24.5
Mutton, leg, lean		1.0		0.54	2.3	0.2	1.4	0.9	—	3.4	—	++
		3.5	2 slices, 3¼"x4½"x⅛"	1.91	7.9	0.6	4.9	3.2		12.0		
	52	1.9	1 slice, 3½"x4½"x⅛"	1.00	4.2	0.3	2.6	1.7		6.3		
Mutton, leg, roasted	33	1.2	1 slice, 3"x3¾"x⅛"	1.00	3.3	0.2	2.0	2.5	—	+	—	++
Nabisco wafers		1.0		1.42	0.6							
		3.5	25 wafers	4.99	2.1							
	20	0.7	5 wafers, 2½"x1"x¼"	1.00	0.4							
Nectarines, yellow		1.0		0.19	0.1	—	0.2	0.3	5.7			
		3.5		0.67	0.2	0.2	0.5	1.0	20.0			
	150	5.3	2 small	1.00	0.3	0.3	0.8	1.5	30.0			
Oats, rolled, cooked	136	4.8	¾ cup	1.00	1.7	0.7	2.2	2.4	—	3.0	—	+
Oats, rolled, uncooked		1.0		1.13	1.9	0.8	2.5	2.7	—	3.9	—	+
		3.5	1⅓ cups	3.97	6.7	2.7	8.8	9.6		13.8		
	25	0.9	⅓ cup	1.00	1.7	0.7	2.2	2.4		3.5		
	71	2.5	1 cup	2.80	4.7	1.9	6.2	6.8		9.8		

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight: Gms.	Weight: Oz.	Approximate Measure	Shares: Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Okra		1.0		0.11	0.2	0.9	0.4	0.4	1.7	++		+
		3.5	10–12 pods	0.38	0.6	3.1	1.4	1.2	6.0			
	263	9.2	25–30 pods	1.00	1.7	8.6	3.9	3.4	15.8			
Oleomargarine		1.0		2.13	0.1	0.4	0.2	0.2		—	—	—
		3.5	7 tbsp.	7.52	0.5	1.4	0.8	0.8				
	13	0.5	1 tbsp.	1.00	0.1	0.2	0.1	0.1				
Olive oil		1.0		2.55	—	—	—	—	0.1	—	—	—
		3.5	½ cup	9.00					0.3			
	11	0.4	1 tbsp.	1.00								
	207	7.3	1 cup	18.81					0.6			
Olives, green, stoned		1.0		0.36	0.1	1.5	0.1	1.7	0.8	0.1		
		3.5	12 large	1.28	0.5	5.3	0.3	5.8	2.8	0.3		
	78	2.8	8 large or 12–16 medium	1.00	0.4	4.1	0.3	4.5	2.2	0.2		
Olives, ripe, unstoned (Manzanilla)	66	2.3	8–10 medium	1.00	0.3	3.0	0.2	3.2	1.4	0.2		
Onions		1.0		0.14	0.2	0.5	0.3	0.3	—	0.3	2(R)*	0.2
		3.5	1 large or ½ cup, sliced	0.49	0.6	1.8	1.1	1.2		1.0	8(R)*	0.7
	205	7.2	3–4 medium	1.00	1.3	3.6	2.2	2.0		2.1	15(R)*	1.4
	62	2.2	1 medium	0.30	0.4	1.1	0.7	0.6		0.6	5(R)*	0.4

* About one-third lost in cooking.

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Orange juice, fresh or canned		1.0		0.16	0.1	0.2	0.1	0.1	0.2	2.3	9	0.5
		3.5	½ cup (scant)	0.56	0.2	0.8	0.3	0.5	0.7	8.0	33	1.8
	183	6.4	¾ cup	1.00	0.4	1.5	0.5	0.9	1.3	14.6	60	3.2
	14	0.5	1 tbsp.	0.08	—	0.1	—	0.1	0.1	1.1	5	0.2
Oranges		1.0		0.14	0.1	0.3	0.1	0.3	0.2*	2.0*	8*	0.5*
		3.5	1 small orange	0.50	0.4	1.1	0.5	1.0	0.6	7.1	29	1.5
	204	7.2	1 cup, ½″ pieces	1.00	0.7	2.3	0.9	2.1	1.3	14.5	59	3.1
	156 (214 A. P.)	5.5	1 medium	0.80	0.6	1.8	0.7	1.6	0.9	11.1	45	2.5
Oysters		1.0		0.14	0.7	0.7	1.0	3.5	0.6	4.3	—	++
		3.5	⅓ cup solids	0.50	2.5	2.4	3.4	11.6	2.0	15.0	3	
	198	7.0	6–15 oysters or ⅔ cup solids	1.00	4.9	4.9	6.8	23.2	4.0	29.7	5	
Pablum		1.0		1.05	1.7	9.6	4.0	17.0				
		3.5	2½ cups	3.70	6.0	33.9	14.1	60.0				
	27	1.0	12 tbsp.	1.00	1.6	9.2	3.8	16.2				
Papayas		1.0		0.12	0.1	0.2	0.1	0.2	11.9	0.3	5	
		3.5		0.43	0.2	0.8	0.3	0.6	42.0	1.2	18	
	231	8.2		1.00	0.6	1.9	0.7	1.4	97.6	2.8	41	

* Calculated from orange juice.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Parsnips		1.0		0.18	0.2	0.7	0.5	0.4	—	2.1		
		3.5	½ cup, cubes	0.65	0.6	2.6	1.7	1.5		7.5		
	154 (192 A. P.)	5.4	1 parsnip, 7″ long, 2″ diam. at top.	1.00	1.0	4.0	2.6	2.4		11.6		
	165	5.8	7 pieces, $3\frac{1}{2}''\times1\frac{1}{2}''\times\frac{1}{3}''$ steamed	1.00	1.0	4.0	2.6	2.4		11.6		
Peaches, canned*		1.0		0.13	0.1	0.1	0.1	0.1			—	
		3.5	1 large half plus 1½ tbsp. juice	0.47	0.3	0.4	0.3	0.4			3†	
	213	7.5	2 large halves plus 3 tbsp. juice	1.00	0.6	0.9	0.7	0.8			6†	
Peaches, dried		1.0		0.89	0.5	0.7	0.8	3.5				
		3.5		3.12	1.6	2.6	2.7	12.2				
	32	1.1		1.00	0.5	0.8	0.9	3.9				
Peaches, fresh, yellow		1.0		0.14	0.1	—	0.1	0.2	5.7‡	+	2	
		3.5	1 medium	0.53	0.2	0.4	0.4	0.6	20.0‡		5	
	196 (222 A. P.)	6.9	2 medium	1.00	0.4	0.9	1.0	1.3	39.2‡		9	
Peanut butter	17	0.6	1 tbsp. (scant)	1.00	1.9	0.5	1.5	0.6	+	4.0	—	1.8

* Ash calculated on 100 grams fresh fruit plus 60 grams of 15 per cent syrup.

† Elbertas.

‡ Elbertas, none in white.

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Peanuts, roasted		1.0		1.55	2.9	0.8	2.5	1.1	+	6.2	—	2.9
		3.5	¾ cup shelled	5.48	10.3	2.9	8.7	4.0		22.0		10.0
	18	0.6	20 kernels	1.00	1.9	0.5	1.7	0.7		4.0		1.8
	9	0.3	1 tbsp., chopped	0.50	1.0	0.3	0.9	0.4		2.0		0.9
Pears, canned*		1.0		0.18	—	0.1	0.1	0.1				
		3.5	2 halves and 2 tbsp. juice	0.62	0.2	0.4	0.4	0.4				
	162	5.7	3 halves and 3 tbsp. juice	1.00	0.3	0.6	0.6	0.6				
Pears, fresh		1.0		0.18	0.1	0.2	0.1	0.2	—	1.0	1	0.7
		3.5	1 large	0.63	0.2	0.7	0.4	0.6	0.1	3.5	4	2.5
	158	5.6	2 medium	1.00	0.4	1.0	0.6	1.2	0.2	5.5	6	4.0
Pea soup, cream of		1.0		0.30	0.4	1.2	0.6	0.4	1.1	0.2	—	0.6
		3.5	⅜ cup	1.06	1.5	4.0	2.0	1.5	3.9	0.7	1	2.1
	94	3.3	⅜ cup	1.00	1.4	3.8	1.9	1.4	3.7	0.7	1	2.0
Peas, canned, drained		1.0		0.19	0.5	0.2	0.5	0.7	+	+	—	+
		3.5	⅓ cup	0.67	1.8	0.7	1.9	2.6				
	148	5.2	½ cup	1.00	2.7	1.0	2.8	3.8				

* Calculated on 100 grams of fresh fruit plus 60 grams of 25 per cent syrup.

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Peas, canned,		1.0		0.16	0.4	0.2	0.5	0.6	+	+	+	+
including		3.5	½ cup	0.55	1.4	0.6	1.6	2.2				
liquor*	181	6.4	⅞ cup	1.00	2.6	1.1	2.9	4.0				
Peas,		1.0		1.00	2.8	0.4	1.7	3.1	+	++	–	+
dried,		3.5	½ cup	3.55	9.8	1.4	6.1	10.8				
split	28	1.0	2 tbsp.	1.00	2.8	0.4	1.7	3.1				
	213	7.5	1 cup	6.75	18.8	6.5	13.0	23.0				
Peas,		1.0		1.01	2.8	1.0	2.6	3.2	3.5	17.0	–	5.0
dried,		3.5	½ cup	3.55	9.8	3.4	9.3	11.4	12.5	60.0		18.5
whole	28	1.0	⅙ cup	1.00	2.8	1.0	2.6	3.2	3.5	17.0		5.0
Peas,		1.0		0.28	0.8	0.3	0.8	1.2	2.8	8.5(R)†	6(R)‡	1.4
fresh, green,	100	3.5	¾ cup	1.00	2.8	1.0	2.9	4.0	10.0	30.0(R)†	20(R)‡	5.0
shelled												
Peas,		1.0		0.14	0.4	0.1	0.3	1.4	1.9	1.2	2	0.4
strained,	128	4.5	½ cup	0.63	1.8	0.6	1.3	6.1	8.7	5.1	8	1.9
canned	15	0.5	1 tbsp.	0.07	0.2	0.1	0.2	0.7	1.0	0.6	1	0.2
Pecans,		1.0		2.08	1.1	1.1	2.2	1.5	0.6	2.8	–	
shelled		3.5	⅔ cup	7.34	3.8	3.9	7.6	5.2	2.0	10.0		
	14	0.5	12 meats	1.00	0.5	0.5	1.0	0.7	0.3	1.4		

* Averages 27 to 50 per cent of total weight. † About 25 per cent lost in cooking when all water retained.
‡ About 10 per cent lost in cooking when all water retained; 50 per cent dissolved in cooking water.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Peppers, green		1.0		0.08	0.1	0.1	0.2	0.2	2.3*	0.3	29(R)	+
		3.5		0.28	0.5	0.5	0.6	0.8	8.0*	1.2	100(R)	
	346	12.2	5 peppers, $3\frac{1}{2}''$ long	1.00	1.6	1.8	2.2	2.7	27.7*	4.2	345(R)	
Pigeon, *see* Squab												
Pineapple, canned, 40 per cent syrup		1.0		0.27	—	—	—	0.1	0.1	0.7	3	0.2
		3.5		0.96	0.1	0.2	0.2	0.4	0.3	2.5	10	0.5
	104	3.7	2 slices, 3 tbsp. juice	1.00	0.1	0.2	0.2	0.4	0.3	2.6	11	0.5
Pineapple, fresh		1.0		0.16	—	0.1	0.1	0.2	0.2	1.4	4	0.4
		3.5		0.57	0.1	0.4	0.3	0.7	0.6	5.0	13	1.3
	174	6.2	2 slices, $\frac{3}{4}''$ thick	1.00	0.3	0.6	0.4	1.3	1.0	8.7	22	2.2
	162	5.7	1 cup, $\frac{1}{2}''$ pieces	0.92	0.2	0.6	0.4	1.2	1.0	8.1	20	2.0
Pineapple juice, canned		1.0		0.19	—	0.2	0.1	0.1	0.3	2.0	2	0.2
		3.5	$\frac{1}{2}$ cup (scant)	0.65		0.7	0.3	0.2	1.1	7.0	7	0.5
	152	5.3	$\frac{2}{3}$ cup	1.00		1.0	0.4	0.3	1.6	10.6	11	0.8
Plums		1.0		0.16	0.1	0.3	0.2	0.3		2.3	2	
		3.5		0.56	0.4	0.9	0.6	1.1		8.0	5	
	181 (217 A. P.)	6.4	4 plums, $1\frac{3}{4}''$ diam.	1.00	0.5	1.6	1.1	2.0		14.6	9	

* Red pimientos 6–7 times as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Pomegranate juice		1.0		0.13	—	—	—	0.1				
		3.5	½ cup (scant)	0.47	0.1	0.1	0.2	0.4				
	213	7.5	1 cup	1.00	0.2	0.3	0.4	0.9				
Pork, loin chops, lean		1.0		0.72	2.3	0.1	1.3	0.9	+	8.5	—	1.4
		3.5		2.52	8.1	0.4	4.5	3.0		30.0		5.0
	40	1.4		1.00	3.2	0.2	1.8	1.2		12.0		2.0
	56	2.0	1 chop, broiled	2.00	6.4	0.2	4.5	3.0				
	68	2.4	1 chop, broiled, lean meat	2.00	6.4	0.4	3.9	4.8				
Pork, roast, fat largely removed		1.0		0.48	3.4	0.2	2.1	3.1	+	++	—	++
		3.5	1 piece, 3″x4¼″x¼″	1.69	11.9	0.7	7.3	11.0				
	59	2.1	1 piece, 3″x2½″x¼″	1.00	7.0	0.4	4.3	6.5				
Pork sausage		1.0		1.28	1.5	—	0.2	0.1	+	++	—	++
		3.5		4.52	5.2	0.1	0.6	0.4				
	22	0.8		1.00	1.1	—	0.1	0.1				
	31	1.1	1⅔ sausages, 3″ long, ¾″ diam., cooked	1.00	1.1	—	0.1	0.1				
Potatoes, French fried		1.0		0.71	0.4	0.2	0.5	0.8	—	+	—	+
		3.5		2.51	1.5	0.6	1.6	2.8				
	40	1.4		1.00	0.6	0.3	0.7	1.1				

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Potatoes, sweet		1.0		0.35	0.2	0.3	0.3	0.4	7.3	2.0	2	0.5
		3.5	$\frac{2}{3}$ medium	1.23	0.7	0.8	1.0	1.5	25.7	7.0	7	1.8
	81 (101 A. P.)	2.9	$\frac{1}{2}$ medium	1.00	0.6	0.7	0.8	1.3	20.8	5.7	6	1.4
Potatoes, white		1.0		0.24	0.2	0.1	0.3	0.5	0.1	1.1	2(CK)	0.4
		3.5	$\frac{3}{4}$ cup, riced	0.83	0.8	0.5	1.2	1.8	0.3	4.0	6(CK)	1.3
	120 (150 A. P.)	4.2	$\frac{3}{4}$ cup, $\frac{1}{2}''$ cubes or 1 medium	1.00	1.1	0.6	1.5	2.2	0.3	4.8	7(CK)	1.5
	85	3.0	1 medium, baked	1.00	1.1	0.6	1.5	2.2	0.3	4.8	7(CK)	1.5
Prunes, dried, stoned		1.0		0.86	0.2	0.7	0.6	1.6	5.7	2.1	2	3.7
		3.5	12 medium	3.02	0.8	2.3	1.9	5.8	20.0	7.5	8	13.0
	33 (39 A. P.)	1.2	4 medium	1.00	0.3	0.8	0.6	1.9	6.7	2.5	2	4.8
Prunes, strained, canned		1.0		0.29	0.1	0.3	0.3	2.4				
	128	4.5	$\frac{1}{2}$ cup	1.32	0.5	1.3	1.1	10.8				
	15	0.5	1 tbsp.	0.15	0.1	0.2	0.1	1.3				
Pumpkin pie		1.0		0.45	0.5	0.8	0.6	0.4	1.2	0.6		0.6
		3.5		1.59	1.9	2.7	2.0	1.5	4.1	2.2		2.2
	62	2.2	$1\frac{1}{4}''$ sector, $9''$ diam.	1.00	1.2	1.7	1.2	0.9	2.6	1.4		1.4
	229	8.1	$4\frac{1}{2}''$ sector, $9''$ diam.	3.67	4.4	6.3	4.6	3.5	9.5	5.0		5.2

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Pumpkins, fresh		1.0		0.07	0.1	0.3	0.3	0.5	++	+	2	
		3.5		0.26	0.4	1.0	1.1	1.8			5	
	389	13.7		1.00	1.6	3.9	4.0	7.2			19	
	184	6.5	1 cup, steamed	0.70	1.1	2.7	2.8	5.0				
Radishes		1.0		0.08	0.2	0.4	0.2	0.5	—	0.7	7	
		3.5	10 red button	0.29	5.2	1.3	0.7	1.6		2.5	25	
	341	12.0	3 doz. red button	1.00	1.8	4.6	2.4	5.7		8.5	85	
Raisins		1.0		1.00	0.3	0.7	0.9	1.7	0.3	1.7	—	0.7
		3.5		3.45	1.0	2.6	3.0	6.0	1.0	6.0		2.5
	29	1.0	¼ cup seeded or 2 tbsp. seedless	1.00	0.3	0.7	0.9	1.7	0.3	1.7		0.7
	142	5.0	1¼ cups, seeded	4.90	1.5	3.7	4.2	8.6	1.4	8.5		3.6
Raspberries, fresh		1.0		0.19	0.2	0.5	0.3	0.5	++	+	2	
		3.5	¾ cup	0.66	0.7	1.8	0.9	1.8			8	
	151	5.3	1⅛ cups	1.00	1.0	2.6	1.3	2.7			12	
Rhubarb		1.0		0.05	0.1	0.5	0.1	0.3			5(R)	
		3.5	⅞ cup, 1″ pieces	0.18	0.2	1.9	0.4	1.1			18(R)	
	556	19.6	5 cups, 1″ pieces	1.00	1.1	10.6	2.3	6.2			93(R)	
Rice, brown, uncooked		1.0		1.00	0.9	0.8	2.2	1.1	—	3.1	—	—
		3.5	½ cup	3.51	3.2	2.8	7.6	4.0		11.0		
	29	1.0	2 tbsp.	1.00	0.9	0.8	2.2	1.1		3.1		

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Rice, white, puffed		1.0		1.00	0.9	0.1	0.6	0.5	—	—	—	—
		3.5		3.51	3.2	0.4	2.2	1.8				
	27	1.0	$1\frac{2}{3}$ cups	1.00	0.9	0.1	0.6	0.5				
	12	0.4	$\frac{3}{4}$ cup	0.45	0.4	0.1	0.3	0.2				
Rice, white, uncooked		1.0		1.00	0.9	0.1	0.6	0.5	—	—	—	—
		3.5	$\frac{1}{2}$ cup	3.51	3.2	0.4	2.2	1.8				
	29	1.0	2 tbsp.	1.00	0.9	0.1	0.6	0.5				
	14	0.5	1 tbsp.	0.50	0.5	0.1	0.3	0.3				
	198	7.0	1 cup	6.96	6.3	0.9	4.3	3.6				
	113	4.0	$\frac{3}{4}$ cup, steamed	1.00	0.9	0.1	0.6	0.5				
Rutabagas		1.0		0.12	0.2	1.0	0.4	0.3	—	0.9	6	0.6
		3.5	$\frac{2}{3}$ cup, $\frac{1}{2}''$ cubes	0.41	0.5	3.1	1.3	1.1	0.2	3.0	20	2.0
	244	8.6	$1\frac{2}{3}$ cups, $\frac{1}{2}''$ cubes	1.00	1.3	8.0	3.2	2.4	0.5	7.3	49	4.9
	703 (1010 A. P.)	24.8	1 large, $7\frac{1}{2}''$ long, $4\frac{1}{2}''$ diam.	2.88	3.6	23.2	9.2	7.4	1.4	21.1	141	14.1
Rye wafer (whole rye)		1.0		0.99	1.5		2.5	2.2				
		3.5		3.50	5.2		8.8	7.8				
	29	1.0	$3\frac{1}{2}$ wafers, $3\frac{1}{2}''$x$1\frac{3}{4}''$x$\frac{1}{8}''$	1.00	1.5		2.5	2.2				
	8	0.3	1 wafer	0.28	0.3		0.6	0.5				
Salmon, fresh		1.0		0.58	2.5	0.1	1.6	0.5	+	+		+
		3.5	1 slice, $4''$x$3''$x$\frac{3}{4}''$	2.03	8.8	0.4	5.5	1.7				
	49	1.8	1 slice, $2''$x$3''$x$\frac{3}{4}''$	1.00	4.3	0.2	2.7	0.9				

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Salmon, red, canned		1.0		0.38	2.2	0.8	1.8	0.7	0.9*	0.9		1.2
		3.5	¾ cup	1.33	7.9	2.9	6.5	2.6	3.0*	3.0		4.0
	75	2.7	⅝ cup	1.00	5.9	2.2	4.9	2.0	2.3*	2.3		3.0
Salmon, steamed		1.0		0.55	2.2	0.3	2.0	0.5	+	+		+
		3.5	1 piece, 3″x3¾″x¾″	1.93	7.6	1.3	6.9	1.6				
	52	1.8	1 piece, 3″x1⅞″x¾″	1.00	4.0	0.7	3.6	0.8				
Sardines, canned		1.0		0.76	2.6	0.4	2.4	1.0	+	+		+
		3.5	10 sardines, 3″ long	2.69	9.1	1.5	8.3	3.6				
	37	1.3	4 sardines, 3″ long	1.00	3.4	0.6	3.1	1.3				
Sauerkraut, canned		1.0		0.08	0.2	0.5	0.1	1.9	+	+	3	+
		3.5	⅔ cup, solid	0.27	0.7	1.7	0.2	6.6			10	
	370	13.0	2½ cups, solid	1.00	2.5	6.4	0.8	24.4			37	
Scallops, steamed		1.0		0.29	2.5	1.4	0.2	1.7		+		+
		3.5		1.02	9.0	5.1	0.9	6.0				
	98	3.5	15–20 scallops	1.00	8.8	5.0	0.8	5.9				
Shad, whole, fresh		1.0		0.46	2.1	0.3	1.4	0.6	+	+		+
		3.5	Cross section, 3½″ on back	1.61	7.5	0.9	4.9	2.0				
	62	2.2	Cross section, 2¼″ on back	1.00	4.7	0.5	3.1	1.2				

* Pink one third as much; Chinook twice as much; Chum one tenth as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Shad roe		1.0		0.36	2.4	0.3	1.5	0.7	8.5	4.0		+
		3.5		1.28	8.4	1.0	5.5	2.4	30.0	14.0		
	78	2.8		1.00	6.5	0.8	4.5	1.9	23.4	10.9		
Shortbread		1.0		1.39	0.8							
		3.5		4.88	2.8							
	21	0.7	1 piece, $1\frac{3}{4}''$ square	1.00	0.6							
Shrimp, canned		1.0		0.32	2.9	1.2	1.1	0.8	+	+		+
		3.5		1.11	10.2	4.1	3.9	2.8				
	90	3.2	20 shrimps or $\frac{2}{3}$ cup	1.00	9.1	3.8	3.5	2.5				
Smelts		1.0		0.25	2.0	0.2	1.3	0.6	+	+	–	+
		3.5		0.87	7.0	0.6	4.6	2.0				
	116 (202 A. P.)	4.1	2 fish, 6″ long	1.00	8.1	1.0	5.3	2.3				
Soda, ice cream, chocolate			1 serving	4.00								
Soda, ice cream, vanilla			1 serving	3.00								

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Spinach		1.0		0.07	0.2	*	0.3	1.4	42.0	2.2	13(R)†	1.4
		3.5		0.24	0.8	*	1.0	5.0	148.0	7.7	45(R)†	5.0
	418	14.8	$2\frac{1}{2}$ cups, steamed, chopped	1.00	3.5	*	4.4	21.3	618.6	32.3	185(R)†	20.9
	167	5.9	1 cup, steamed, chopped	0.40	1.5	*	1.8	8.5	247.2	12.9	74(R)†	8.4
Spinach, raw, chopped	5	0.2	1 tbsp.	0.01	—	—	—	0.2	7.4	0.4	2.2	0.3
Spinach, strained, canned		1.0		0.06	0.2	1.5	0.2	0.7	24.5	0.3	2	0.5
	128	4.5	$\frac{1}{2}$ cup	0.27	0.9	6.9	0.7	3.0	110.1	1.3	10	2.2
	15	0.5	1 tbsp.	0.03	0.1	0.8	0.1	0.4	12.9	0.2	1	0.3
Squab		1.0		0.78	2.1	0.1	1.3	1.6		+		+
		3.5		2.73	7.4	0.5	4.6	5.6				
	37	1.3	Lean meat of $\frac{1}{3}$ small bird	1.00	2.7	0.2	1.7	2.1				
	286 (340 A. P.)	10.1	Lean meat of 1 medium bird	7.82	21.1	1.4	13.1	16.0				
Squash, Hubbard		1.0		0.12	0.2	0.2	0.2	0.3	14.2‡			
		3.5	$\frac{1}{2}$ cup, steamed and mashed	0.42	0.6	0.8	0.6	1.1	50.0‡			
	229 (313 A. P.)	8.1	1 cup, steamed	1.00	1.4	1.9	1.5	2.5	114.7‡			

* Calcium omitted as largely unavailable. † At least one fourth lost in cooking. ‡ Zucchini one tenth as much.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Squash, summer		1.0		0.05	0.1	0.2	0.1	0.2	0.9			
		3.5	½ cup, steamed	0.18	0.2	0.8	0.4	0.7	3.0			
	529	18.7	⅔ squash, 5″ diam.	1.00	1.3	4.1	1.9	3.7	15.9			
Strawberries		1.0		0.11	0.1	0.4	0.2	0.4	0.3	+	7	
		3.5	½ cup	0.39	0.4	1.5	0.6	1.4	0.9		25	
	256	9.0	1⅓ cups	1.00	1.0	3.8	1.7	3.5	2.3		64	
Sturgeon, steamed		1.0		0.43	2.8	0.5	1.7	1.1	+	+	–	+
		3.5	1 piece, 3″x1½″x1″	1.50	9.9	1.7	6.0	4.0				
	67	2.4	1 piece, 3″x1″x1″	1.00	6.6	1.2	4.0	2.7				
Suet		1.0		2.14	0.5	–	–	–	–	–	–	–
		3.5	1 cup	7.55	1.9							
	13	0.5	⅛ cup	1.00	0.2							
Sugar, brown		1.0		1.08	–	–	–	–	–	–	–	–
		3.5	⅝ cup	3.80								
	26	0.9	3 tbsp.	1.00								
	165	5.8	1 cup	6.25								
Sugar, granulated		1.0		1.13	–	–	–	–	–	–	–	–
		3.5	½ cup	4.00								
	25	0.9	2 tbsp.	1.00								
	13	0.5	1 tbsp.	0.50								
	210	7.4	1 cup	8.40								

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Sugar, loaf	25	0.9	4 pieces, $1\frac{1}{8}''$x$\frac{3}{4}''$x$\frac{3}{8}''$	1.00	—	—	—	—	—	—	—	—
Sugar, maple		1.0		0.94	—	—	—	—	—	—	—	—
		3.5		3.31								
	30	1.1	1 piece, $1\frac{3}{4}''$x$1\frac{1}{4}''$x$\frac{1}{2}''$	1.00								
Sugar, powdered		1.0		1.13	—	—	—	—	—	—	—	—
		3.5	$\frac{5}{8}$ cup	4.00								
	25	0.9	$2\frac{3}{4}$ tbsp.	1.00								
	170	6.0	1 cup	6.80								
Sundae, with caramel sauce			1 serving	3.50								
Sundae, with chocolate nut sauce			1 serving	3.50								
Sweetbreads, steamed		1.0		0.49	2.6	0.2	3.8	0.9	+	+		+
		3.5	$\frac{3}{4}$ cup	1.73	9.1	0.6	13.5	3.2				
	58	2.1	$\frac{3}{8}$ cup (scant)	1.00	5.2	0.4	7.8	1.8				
Tangerines		1.0		0.14	0.1	0.5	0.1	0.2			7	
		3.5	$1\frac{1}{2}$ medium	0.49	0.4	1.8	0.4	0.6			25	
	204	7.2	3 medium	1.00	0.7	3.7	0.8	1.2			51	

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Tapioca		1.0		1.00	—	0.2	—	0.9	—	—	—	—
		3.5	½ cup	3.55	0.1	0.7	0.1	3.2				
	28	1.0	2 tbsp.	1.00	—	0.2	—	0.9				
	184	6.5	1 cup	6.53	0.3	1.3	0.3	5.8				
Tomato catsup		1.0		0.33	0.3	0.1	0.1	0.5				
		3.5		1.17	1.0	0.5	0.4	1.8				
	86	3.0		1.00	0.8	0.4	0.3	1.5				
Tomato juice, canned		1.0		0.07	0.1	0.1	0.1	0.3	1.4	0.9	5	0.3
		3.5	½ cup (scant)	0.24	0.4	0.3	0.3	1.2	6.0	3.0	15	1.0
	417	14.7	2 cups (scant)	1.00	1.7	1.1	1.4	5.0	25.0	12.5	63	4.2
	15	0.5	1 tbsp.	0.04	0.1	—	0.1	0.2	0.9	0.5	2	0.2
Tomato soup, cream of		1.0		0.33	0.4	1.2	0.6	0.2	1.7	0.7	3	0.7
		3.5	½ cup (scant)	1.15	1.3	4.3	2.0	0.7	5.9	2.5	11	2.6
	86	3.0	⅜ cup	1.00	1.1	3.8	1.7	0.7	5.1	2.2	10	2.3
	172	6.1	¾ cup	2.00	2.3	7.5	3.4	1.3	10.2	4.4	19	4.5
Tomatoes, canned		1.0		0.06	0.1	0.1	0.2	0.3	2.2	1.0	5	0.3
		3.5	⅜ cup	0.23	0.5	0.4	0.7	0.9	7.9	3.5	18	1.0
	485	17.1	2 cups	1.00	2.3	2.1	3.2	4.3	38.1	17.0	85	4.9
Tomatoes, fresh, whole	485	17.1	2–3 large	1.00	2.3	2.1	3.2	4.3	38.1	17.0	85	4.9

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Tomatoes,		1.0		0.05	0.8	0.2	0.2	0.9	8.7	1.9	4	0.3
strained,	128	4.5	½ cup	0.22	3.6	0.7	0.9	4.1	39.2	8.6	15	1.2
canned	15	0.5	1 tbsp.	0.03	0.4	0.1	0.1	0.5	4.7	1.0	2	0.1
Tongue,		1.0		0.85	2.2	0.4	1.5	3.9	+	+	–	+
pickled,		3.5		3.01	7.6	1.3	5.2	13.8				
boiled	33	1.2		1.00	2.5	0.4	1.7	4.6				
Trout,		1.0		0.34	2.5	0.4	1.8	0.6	+	+	–	+
steamed		3.5	1 piece, 2″x3″x¾″	1.20	8.9	1.6	6.1	2.0				
	83	2.9	1 piece, 2″x2½″x¾″	1.00	7.4	1.3	5.1	1.7				
Trout,		1.0		0.47	2.0	0.2	1.3	0.6	+	+	–	+
uncooked		3.5	1 piece, 2″x3″x1″	1.64	7.1	0.8	4.6	2.0				
	61	2.2	1 piece, 2″x2″x1″	1.00	4.3	0.5	2.8	1.2				
Tuna fish,		1.0		0.79	2.9	0.4	1.9	0.8	+	+	–	+
canned in		3.5	½ cup	2.78	10.2	1.2	6.6	2.8				
oil	36	1.3	¼ cup (scant)	1.00	3.7	0.4	2.4	1.0				
Tuna fish,		1.0		0.35	2.5	0.3	1.6	0.7	+	+	–	+
canned		3.5	⅝ cup	1.24	8.7	1.0	5.7	2.4				
without oil	81	2.9	½ cup	1.00	7.0	0.8	4.6	1.9				
Turkey meat,		1.0		0.56	4.4	0.3	2.7	3.3	+	+	–	+
dark, cooked		3.5		1.96	15.7	1.0	9.6	11.8				
	51	1.8	1 slice, 4″x2½″x¼″	1.00	8.0	0.5	4.9	6.0				

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight Gms.	Weight Oz.	Approximate Measure	Shares Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Turkey meat, light, cooked		1.0		0.52	3.9	0.3	2.4	3.0	+	+	−	+
		3.5		1.83	13.8	0.9	8.5	10.4				
	55	1.9	1 slice, 4″x2¼″x¼″	1.00	7.6	0.5	4.7	5.7				
Turnip greens		1.0		0.10	0.3	4.3	0.3	2.0	19.9	0.9(CK)*	3(CK)†	4.3
		3.5	⅝ cup, steamed	0.35	1.2	15.0	1.1	6.9	70.0	3.0(CK)*	12(CK)†	15.0
	272	9.6	1⅔ cups, steamed	1.00	3.2	41.0	3.0	18.9	190.0	8.1(CK)*	33(CK)†	40.8
Turnips, white		1.0		0.10	0.1	0.7	0.3	0.3	−	0.9	6	0.6
		3.5	¾ cup, ½″ cubes	0.35	0.5	2.4	1.1	1.0		3.0	20	2.0
	289	10.2	2 cups, ½″ cubes	1.00	1.4	7.0	3.1	3.0		8.6	57	5.7
Veal cutlet, broiled		1.0		0.41	3.2	0.2	1.5	1.7	−	+	−	+
		3.5	1 piece, 3″x3″x⅝″	1.44	11.4	0.6	5.2	6.0				
	69	2.4	1 piece, 2″x3″x⅝″	1.00	7.9	0.4	3.6	4.2				
Veal, leg, lean		1.0		0.35	2.4	0.2	1.5	1.5	−	+	−	2.2
		3.5	1 slice, 3½″x4″x¼″	1.22	8.5	0.6	5.2	5.2				7.5
	82	2.9	1 slice, 3″x4″x¼″	1.00	7.0	0.5	4.1	4.1				6.2
Veal, leg, lean, roasted	65	2.3	1 slice, 2″x2¾″x⅛″	1.00	7.1	0.5	4.3	5.3	−	+	−	+
Vegetable soup, strained, canned		1.0		0.12	0.2	0.2	0.2	0.5				
	128	4.5	½ cup	0.54	0.8	1.0	0.7	2.0				
	15	0.5	1 tbsp.	0.06	0.1	0.1	0.1	0.2				

* 10 per cent lost in cooking.

† 90 per cent lost in cooking.

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Vegetable soup, thick		1.0		0.12	0.1	0.2	0.2	0.3	0.7	0.1	1	0.2
		3.5	$\frac{3}{8}$ cup	0.43	0.3	0.8	0.6	1.0	2.5	0.3	2	0.7
	230	8.1	$\frac{7}{8}$ cup	1.00	0.8	1.8	1.4	2.3	5.8	0.7	5	1.5
	258	9.1	1 cup	1.12	0.9	2.0	1.5	2.5	6.5	0.8	5	1.7
Walnuts, English		1.0		2.00	2.1	1.1	2.3	1.2	+	8.5	—	
		3.5	1¼ cups (scant)	7.03	7.4	3.9	8.1	4.2		30.0		
	14	0.5	8–16 meats or 1¼ tbsp. chopped	1.00	1.0	0.6	1.2	0.6		4.3		
Water chestnuts		1.0		0.25	0.2					1.0		
		3.5		0.89	0.6					3.5		
	112	4.0		1.00	0.6					3.9		
Watercress		1.0		0.06	0.2	1.9	0.3	1.7	2.3	1.7	14	1.4
		3.5	1 bunch	0.22	0.7	6.8	1.0	5.9	8.0	6.0	50	5.0
	440	15.5	5 bunches, 3″ long, 3″ diam.	1.00	3.1	31.0	4.8	27.0	36.3	27.3	228	22.8
Watermelons		1.0		0.09	—	0.1	0.1	0.1	0.3	0.5	2	0.2
		3.5	1 slice, 2½″x2½″x1″	0.30	0.2	0.4	0.3	0.5	0.9	1.7	7	0.6
	331	11.7	1 slice, ¾″ thick, 6″ diam.	1.00	0.5	1.2	1.0	1.5	3.0	5.6	23	2.0

TABLE I—*Continued*

NUTRITIVE VALUES OF FOODS IN SHARES

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Wheat, flaked		1.0		1.00	1.5	0.5	2.3	2.0	—	4.3	—	1.2
		3.5		3.63	5.4	1.7	8.3	5.4	0.2	15.0		4.0
	28	1.0	$\frac{1}{3}$ cup	1.00	1.5	0.5	2.3	2.0	—	4.2		1.1
	85	3.0	1 cup	3.09	4.5	1.5	6.9	6.0	0.1	12.8		3.4
Wheat, flaked, cooked	170	6.0	$\frac{2}{3}$ cup	1.00	1.5	0.5	2.3	2.0	—	3.6	—	+
Wheat germ		1.0		1.14	4.2	0.9	6.8	4.3		34.0		4.3
		3.5	$\frac{3}{4}$ cup	4.03	14.9	3.1	23.9	15.0		120.0		15.0
	25	0.9	3 tbsp.	1.00	3.7	0.8	5.9	3.7		30.0		3.8
Wheat, puffed		1.0		1.06	1.8	0.5	2.7	2.3	+	—	—	+
		3.5		3.74	6.5	1.8	9.5	8.2				
	27	1.0	2 cups	1.00	1.7	0.5	2.5	2.2				
Wheat, shredded		1.0		1.04	1.4	0.5	2.1	2.6	—	2.8	—	1.2
		3.5	$3\frac{1}{2}$ biscuits	3.65	4.8	1.8	7.3	9.1	0.2	10.0		4.0
	27	1.0	1 biscuit	1.00	1.3	0.5	2.0	2.5	—	2.8		1.1
Yautia		1.0		0.32	0.2				0.1	1.0		
		3.5		1.13	0.9				0.5	3.5		
	88	3.1		1.00	0.8				0.4	3.1		

TABLE I—*Continued*

Nutritive Values of Foods in Shares

Food Material	Weight		Approximate Measure	Shares								
	Gms.	Oz.		Cal.	Pro.	Ca	P	Fe	Vit. A	Vit. B	Vit. C	Vit. G
Yeast,		1.0		0.38	1.3					10.1		16.8
bakers',		3.5		1.34	4.7					35.3		59.3
compressed	74	2.6	5 cakes	1.00	3.5					26.5		44.2
Yeast,		1.0		0.98	5.5					28.4		21.3
bakers',		3.5		3.46	19.4					100.0		75.0
dried	29	1.0		1.00	5.6					28.9		21.7
Yeast,		1.0		0.98	5.6	9.8				141.8		19.8
brewers',		3.5		3.45	19.8	34.2				500.0		70.0
dried	29	1.0		1.00	5.7	10.0				144.9		20.3
Yeast extract		1.0		0.40	3.7	12.1	1.7	27.2	—	127.6	—	63.8
(Vegex)		3.5		1.38	13.0	42.6	6.0	96.0		450.0		225.0
	72	2.6		1.00	9.4	30.6	4.3	69.1		324.0		162:0

TABLE II

Working Plans for the Construction of Adequate Diets

PART I

A. For Pre-School Children

Age	Per Cent of Total Calories from Each Class of Food					
	Food from Cereal Grains	Milk	Vegetables and Fruits	Butter	Sugar	Egg Yolk
1–2 years	10–20	65–75	5–10	1–3	0–1	2–3
2–3 years	18–20	55–60	10–12	3–4	1–2	3–4
3–4 years	20–22	50–55	12–14	4–5	1–3	4–5
4–5 years	23–25	45–50	14–18	5–8	2–5	5–6

B. For Elementary School Children

Age	Per Cent of Total Calories from Each Class of Food					
	Food from Cereal Grains	Milk	Vegetables and Fruits	Fats	Sugar	Eggs, Cheese, Meat, and Other Flesh Foods
6–7 years	20–25	40–45	14–15	10–12	3–4	4–5
8–9 years	20–25	38–42	15–16	12–13	4–6	5–6
10–12 years	20–25	34–38	17–18	13–14	6–8	7–8

C. For High School Boys and Girls

Calorie Requirement	Per Cent of Total Calories from Each Class of Food					
	Food from Cereal Grains	Milk	Vegetables and Fruits	Fats	Sugar	Eggs, Cheese, Meat, and Other Flesh Foods
2,000	16–18	30–33	18–20	15–16	10	10
2,500	18–20	24–25	18–20	16–18	10	10
3,000	20–22	22–23	18–20	16–18	10	10
3,500	24–25	18–20	17–18	17–18	10	10
4,000	25–26	16–18	16–17	17–18	10–12	10–11
5,000	27–28	15–16	16–17	17–18	10–12	11–12

D. For Healthy Adults

Level of Income	Per Cent of Total Calories from Each Class of Food					
	Food from Cereal Grains	Milk	Vegetables and Fruits	Fats	Sugar	Eggs, Cheese, Meat, and Other Flesh Foods
Low	40	18	12	12	10	8
Moderate	30	13	15	17	10	15
High	20	16	20	18	10	16

TABLE II—*Continued*

Working Plans for the Construction of Adequate Diets

E. For a Family of Two Adults and Three Young Children

Level of Income	Per Cent of Total Calories from Each Class of Food					
	Food from Cereal Grains	Milk	Vegetables and Fruits	Fats	Sugar	Eggs, Cheese, Meat, and Other Flesh Foods
Low	35	25	12	12	10	6
Moderate	25	25	17	15	10	8
High	20	25	20	15	10	10

PART II

Dietary Standards in Shares

A. For Children 1–9 Years Old

Age, Years	Weight		Calorie Shares	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamin A Shares	Vitamin B Shares	Vitamin C Shares	Vitamin G Shares
	Lbs.	Kg.									
1	22	10	10	15	43	23	15	20	20	40	20
3	31	14	12	18	43	23	15	20	20	40	20
5	37	17	14	17	43	23	15	20	20	40	20
7	51	23	18	22	43	23	18	20	20	40	20
9	64	29	20	24	43	23	20	20	20	40	20

B. For Boys and Girls 10–18 Years Old

Age, Years	Weight		Calorie Shares	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamin A Shares	Vitamin B Shares	Vitamin C Shares	Vitamin G Shares
	Lbs.	Kg.									
*			20	20	43	23	20	20	20	30	20
*			25	25	43	25	25	25	25	30	25
*			30	30	43	30	30	30	30	30	30
*			35	35	43	35	35	35	35	35	35
*			40	40	43	40	40	40	40	40	40
*			50	50	50	50	50	50	50	50	50

* For these ages the ranges in weight are so wide that the energy requirement needs to be determined by weight and height as well as age.

TABLE II—*Continued*

WORKING PLANS FOR THE CONSTUCTION OF ADEQUATE DIETS

C. For an Adult Man and Woman of Average Weight

	Calorie Shares	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamin A Shares	Vitamin B Shares	Vitamin C Shares	Vitamin G Shares
Man* 70 kg.	30	30	30	30	30	30	30	30	30
Woman† 56 kg.	24	24	24	24	28	24	24	24	24

* In each case the shares of other essentials will be the same as the calorie shares.
† In each case the shares of other essentials will be the same as the calorie shares, with the exception of iron, which should be slightly higher, and not fall, in any case of lower calorie intake, below 28 shares.

D. For Reducing Diets

	Calorie Shares	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamin A Shares	Vitamin B Shares	Vitamin C Shares	Vitamin G Shares
	(24)* 10	24	24	24	24	24	24	24	24
	(28)* 12	28	28	28	28	28	28	28	28
	(30)* 15	30	30	30	30	30	30	30	30

* The figures in parentheses indicate the energy requirement for the person without reduction of calories to lose weight.

E. For Pregnancy and Lactation

		Calorie Shares	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamin A Shares	Vitamin B Shares	Vitamin C Shares	Vitamin G Shares
For pregnancy	56 kg.	24	36	70	40	30	60	40	40	40
For lactation	56 kg.	30	48	70	40	30	60	60	60	60

NOTE

Tables III, IV, V, and VI which appear in the following pages give weight and height ranges of American children at different ages from birth to 20 years. Tables III and IV were prepared by Dr. Robert M. Woodbury; and Tables V and VI by Dr. Bird T. Baldwin and Dr. Thomas D. Wood. In their present form they were issued by the American Child Health Association, which gave permission to reproduce them in this book. It must be remembered that these figures are averages of large numbers of children. No child is expected to conform to the exact weight for height and age indicated in these tables. Differences in type of build, in speed of development and many other factors make such arbitrary use impossible. At the same time these tables are most valuable in showing the trend of growth in weight and height from year to year.

TABLE III

Weight—Height—Age Table for Boys from Birth to School Age

Height (Inches)	Average Weight for Height (Pounds)	1 Mo.	3 Mos.	6 Mos.	9 Mos.	12 Mos.	18 Mos.	24 Mos.	30 Mos.	36 Mos.	48 Mos.	60 Mos.	72 Mos.
20	8	8											
21	9½	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14									
25	15	13	14	15	16								
26	16½		15	17	17	18							
27	18		16	18	18	19							
28	19½			19	19	20	20						
29	20½			20	21	21	21						
30	22			22	22	22	22	22					
31	23				23	23	23	23	24				
32	24½				24	24	24	25	25				
33	26					26	26	26	26	26			
34	27						27	27	27	27			
35	29½						29	29	29	29	29		
36	31							30	31	31	31		
37	32							32	32	32	32	32	
38	33½								33	33	33	34	
39	35								35	35	35	35	
40	36½									36	36	36	36
41	38										38	38	38
42	39½										39	39	39
43	41½										41	41	41
44	43½											43	43
45	45½											45	45
46	48												48
47	50												50
48	52½												52
49	55												55

Weight is stated to the nearest pound; height to the nearest inch; age to the nearest month.
Up to and including 34 inches the *weights are net.* Above this the following amounts have been added for clothing (shoes, coats, and sweaters are not included):

35 to 39 in. 1¼ pounds   40 to 44 in. 1½ pounds   45 to 49 in. 1¾ pounds.

TABLE IV

WEIGHT—HEIGHT—AGE TABLE FOR GIRLS FROM BIRTH TO SCHOOL AGE

HEIGHT (INCHES)	AVERAGE WEIGHT FOR HEIGHT (POUNDS)	1 Mo.	3 Mos.	6 Mos.	9 Mos.	12 Mos.	18 Mos.	24 Mos.	30 Mos.	36 Mos.	48 Mos.	60 Mos.	72 Mos.
20	8	8											
21	9	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14	14								
25	15	13	14	15	15								
26	16½		15	16	17	17							
27	17½		16	17	18	18							
28	19			19	19	19	19						
29	20			19	20	20	20						
30	21½			21	21	21	21	21					
31	22½				22	22	23	23	23				
32	24					23	24	24	24	25			
33	25						25	25	25	26			
34	26½						26	26	26	27			
35	29						29	29	29	29	29		
36	30							30	30	30	30	31	
37	31½							31	31	31	31	32	
38	32½								33	33	33	33	
39	34								34	34	34	34	34
40	35½									35	36	36	36
41	37½										37	37	37
42	39										39	39	39
43	41										40	41	41
44	42½											42	42
45	45												45
46	47½												47
47	50												50
48	52½												52

Weight is stated to the nearest pound; height to the nearest inch; age to the nearest month.

Up to and including 34 inches the *weights are net.* Above this the following amounts have been added for clothing (shoes and sweaters are not included):

35 to 39 in. 1 pound   40 to 44 in. 1½ pounds   45 to 49 in. 1¾ pounds

TABLE V

Weight—Height—Age Table for Boys of School Age

Height (Inches)	Average Weight for Height (Lbs.)	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	12 Years	13 Years	14 Years	15 Years	16 Years	17 Years	18 Years	19 Years	Height (Inches)
38	34	34	34*														38
39	35	35	35														39
40	36	36	36*														40
41	38	38	38	38*													41
42	39	39	39	39*	39*												42
43	41	41	41	41*	41*												43
44	44	44	44	44	44*												44
45	46	46	46	46	46*	46*											45
46	48	47*	48	48	48	48*											46
47	50	49*	50	50	50	50*	50*										47
48	53		52	53	53	53	53*										48
49	55		55	55	55	55	55	55*									49
50	58		57*	58	58	58	58	58*	58*								50
51	61			63	61	61	61	61	61*								51
52	64			64	64	64	64	64	64	64*							52
53	68			66*	67	67	67	67	68	68*							53
54	71				70	70	70	70	71	71	72*						54
55	74				72*	72	73	73	74	74	74*						55
56	78				75*	76	77	77	77	78	78	80*					56
57	82					79*	80	81	81	82	83	83*					57
58	85					83*	84	84	85	85	86	87					58
59	89						87	88	89	89	90	90	90				59

60	94						91*	92	92	93	94	95	96				60
61	99							95	96	97	99	100	103	106*			61
62	104							100*	101	102	103	104	107	111	116*		62
63	111							105*	106	107	108	110	113	118	123	127*	63
64	117								109	111	113	115	117	121	126	130*	64
65	123								114*	117	118	120	122	127	131	134	65
66	129									119	122	125	128	132	136	139	66
67	133									124*	128	130	134	136	139	142	67
68	139										134	134	137	141	143	147	68
69	144										137	139	143	146	149	152	69
70	147										143	144	145	148	151	155	70
71	152										148*	150	151	152	154	159	71
72	157											153	155	156	158	163	72
73	163											157*	160	162	164	167	73
74	169											160*	164	168	170	171	74

Age—years		6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Average height (inches)	Short	43	45	47	49	51	53	54	56	58	60	62	64	65	65	
	Medium	46	48	50	52	54	56	58	60	63	65	67	68	69	69	
	Tall	49	51	53	55	57	59	61	64	67	70	72	72	73	73	
Average annual gain (lbs.)	Short	3	4	5	5	5	4	8	9	11	14	13	7	3		
	Medium	4	5	6	6	6	7	9	11	15	11	8	4	3		
	Tall	5	7	7	7	7	8	12	16	11	9	7	3	4		

* In order to extend the range of the tables so as to include weights of children who are taller or shorter than those in these groups there have been added as starred figures estimated weights. All the other weights represent averages for each inch in height and age of the children observed in this study.

TABLE VI

WEIGHT—HEIGHT—AGE TABLE FOR GIRLS OF SCHOOL AGE

Height (Inches)	Average Weight for Height (Lbs.)	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	12 Years	13 Years	14 Years	15 Years	16 Years	17 Years	18 Years	Height (Inches)
38	33	33	33													38
39	34	34	34													39
40	36	36	36	36*												40
41	37	37	37	37*												41
42	39	39	39	39*												42
43	41	41	41	41	41*											43
44	42	42	42	42	42*											44
45	45	45	45	45	45	45*										45
46	47	47*	47	47	48	48*										46
47	50	49*	50	50	50	50	50*									47
48	52		52	52	52	52	53*	53*								48
49	55		54	54	55	55	56	56*								49
50	58		56*	56	57	58	59	61	62*							50
51	61			59	60	61	61	63	65							51
52	64			63*	64	64	64	65	67							52
53	68			66*	67	67	68	68	69	71*						53
54	71				69	70	70	71	71	73*						54
55	75				72*	74	74	74	75	77	78*					55
56	79					76	78	78	79	81	83*					56
57	84					80*	82	82	82	84	88	92*				57
58	89						84	86	86	88	93	96*	101*			58
59	95						87	90	90	92	96	100	103*	104		59

60	101					91*	95	95	97	101	105	108	109	111*	60
61	108						99	100	101	105	108	112	113	116	61
62	114						104*	105	106	109	113	115	117	118	62
63	118							110	110	112	116	117	119	120	63
64	121							114*	115	117	119	120	122	123	64
65	125							118*	120	121	122	123	125	126	65
66	129								124	124	125	128	129	130	66
67	133								128*	130	131	133	133	135	67
68	138								131*	133	135	136	138	138	68
69	142									135*	137*	138*	140*	142*	69
70	144									136*	138*	140*	142*	144*	70
71	145									138*	140*	142*	144*	145*	71

Age-Years		6	7	8	9	10	11	12	13	14	15	16	17	18
Average height (inches)	Short	43	45	47	49	50	52	54	57	59	60	61	61	61
	Medium	45	47	50	52	54	56	58	60	62	63	64	64	64
	Tall	47	50	53	55	57	59	62	64	66	66	67	67	67
Average annual gain (lbs.)	Short	4	4	4	5	6	6	10	13	10	7	2	1	
	Medium	5	5	6	7	8	10	13	10	6	4	3	1	
	Tall	6	8	8	9	11	13	9	8	4	4	1	1	

* In order to extend the range of the tables so as to include weights of children who are taller or shorter than those in these groups there have been added as starred figures estimated weights. All the other weights represent averages for each inch in height and age of the children observed in this study.

TABLE VII

Table of Weight and Height for Men at Different Ages [1]

In ascertaining height—measure yourself in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. Subtract for height of heel, if measured in shoes. Weights are given in pounds.

Height	Age 19 Years	20	21–22	23–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
5 ft.	111	112	114	118	122	126	128	131	133	134	135
5 ft. 1 in.	116	117	118	121	124	128	130	133	135	136	137
5 ft. 2 in.	122	123	124	125	126	130	132	135	137	138	139
5 ft. 3 in.	127	128	128	129	131	133	135	138	140	141	142
5 ft. 4 in.	130	131	132	134	135	136	138	141	143	144	145
5 ft. 5 in.	134	135	136	137	138	140	142	145	147	148	149
5 ft. 6 in.	139	140	141	142	143	144	146	149	151	152	153
5 ft. 7 in.	142	143	144	145	146	148	150	153	155	156	158
5 ft. 8 in.	147	148	149	150	151	152	155	158	160	161	163
5 ft. 9 in.	152	153	154	155	156	158	160	163	165	166	168
5 ft. 10 in.	155	156	157	158	159	162	165	168	170	171	173
5 ft. 11 in.	159	160	161	162	164	166	170	174	176	177	178
6 ft.	163	164	165	166	168	172	176	180	182	183	184
6 ft. 1 in.	167	168	169	171	173	178	182	186	188	190	191
6 ft. 2 in.	171	172	174	176	179	184	189	193	195	197	198
6 ft. 3 in.	175	175	178	181	184	190	195	200	202	204	205
6 ft. 4 in.	178	180	183	186	189	196	201	206	209	211	212
6 ft. 5 in.	183	185	188	191	194	201	207	212	215	217	219

[1] From *Personal Health Standard and Scale*, by Thomas D. Wood, M. D., Bureau of Publications, Teachers College, Columbia University.

TABLE VIII

Table of Weight and Height for Women at Different Ages [1]

In ascertaining height—measure yourself in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. Subtract for height of heel, if measured in shoes. Weights are given in pounds.

Height	Age 19 Years	20	21–22	23–24	25–29	30–34	35–39	40–44	45–49	50–54
4 ft. 10 in.	104	106	108	110	113	116	119	123	126	129
4 ft. 11 in.	106	107	109	112	115	118	121	125	128	131
5 ft.	112	112	113	115	117	120	123	127	130	133
5 ft. 1 in.	116	116	116	118	119	122	125	129	132	135
5 ft. 2 in.	118	118	119	120	121	124	127	132	135	138
5 ft. 3 in.	120	121	122	123	124	127	130	135	138	141
5 ft. 4 in.	123	124	125	126	128	131	134	138	141	144
5 ft. 5 in.	126	127	128	129	131	134	138	142	145	148
5 ft. 6 in.	130	131	132	133	135	138	142	146	149	152
5 ft. 7 in.	135	135	135	137	139	142	146	150	153	156
5 ft. 8 in.	138	138	139	141	143	146	150	154	157	161
5 ft. 9 in.	142	142	142	145	147	150	154	158	161	165
5 ft. 10 in.	144	144	145	148	151	154	157	161	164	169
5 ft. 11 in.	146	147	149	151	154	157	160	164	168	173
6 ft.	150	152	154	156	158	161	163	167	171	176

[1] From *Personal Health Standard and Scale*, by Thomas D. Wood, M. D., Bureau of Publications, Teachers College, Columbia University.

TABLE IX

The Energy Cost of Activities

(Exclusive of Basal Metabolism and Influence of Food)

Activity	Cal. per Kg. per Hr.
Bicycling (century run)	7.6
Bicycling (moderate speed)	2.5
Bookbinding	0.8
Boxing	11.4
Carpentry (heavy)	2.3
Cello playing	1.3
Crocheting	0.4
Dancing, foxtrot	3.8
Dancing, waltz	3.0
Dishwashing	1.0
Dressing and undressing	0.7
Driving automobile	0.9
Eating	0.4
Fencing	7.3
Horseback riding, walk	1.4
Horseback riding, trot	4.3
Horseback riding, gallop	6.7
Ironing (5 lb. iron)	1.0
Knitting sweater	0.7
Laundry, light	1.3
Lying still, awake	0.1
Organ playing ($\frac{1}{3}$ hand work)	1.5
Painting furniture	1.5
Paring potatoes	0.6
Playing ping pong	4.4
Piano playing (Mendelssohn's Songs)	0.8
Piano playing (Beethoven's *Appasionata*)	1.4
Piano playing (Liszt's *Tarantella*)	2.0
Reading aloud	0.4
Rowing in race	16.0
Running	7.0
Sawing wood	5.7
Sewing, hand	0.4
Sewing, foot driven machine	0.6
Sewing, motor driven machine	0.4
Shoemaking	1.0
Singing in loud voice	0.8
Sitting quietly	0.4
Skating	3.5
Standing at attention	0.6
Standing relaxed	0.5
Stone masonry	4.7
Sweeping with broom, bare floor	1.4
Sweeping with carpet sweeper	1.6
Sweeping with vacuum sweeper	2.7
Swimming (2 mi. per hr.)	7.9
Tailoring	0.9

TABLE IX—*Continued*

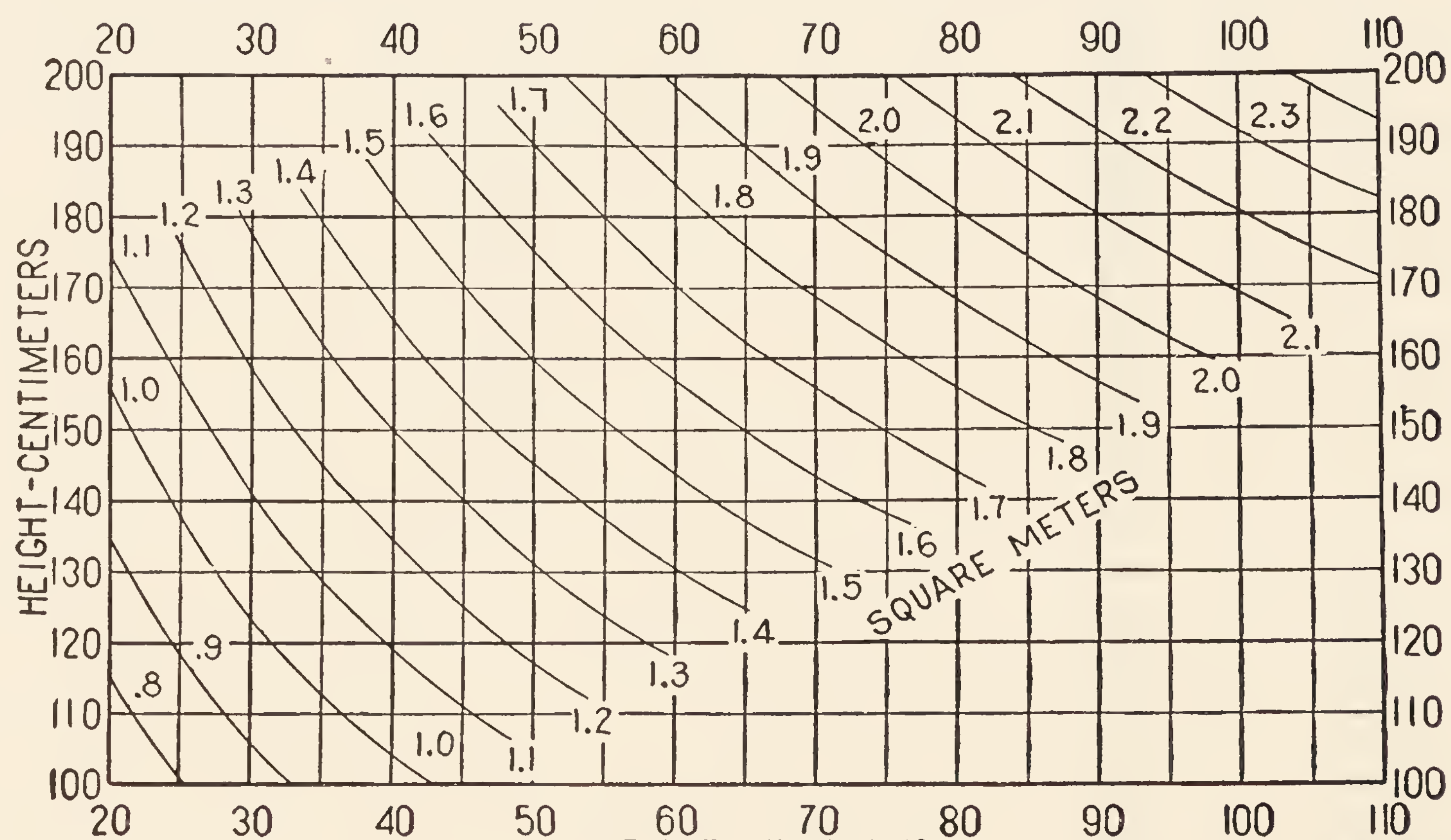
THE ENERGY COST OF ACTIVITIES

(Exclusive of Basal Metabolism and Influence of Food)

Activity	Cal. per Kg. per Hr.
Typewriting rapidly	1.0
Violin playing	0.6
Walking (3 mi. per hr.)	2.0
Walking rapidly (4 mi. per hr.)	3.4
Walking at high speed (5.3 mi. per hr.)	8.3
Walking down stairs	*
Walking up stairs	†
Washing floors	1.2
Writing	0.4

* Allow 0.012 cal. per kg. for an ordinary staircase with 15 steps, without regard to time.
† Allow 0.036 cal. per kg. for an ordinary staircase of 15 steps, without regard to time.

Chart for Determining Surface Area of Adults from Weight and Height



(*Courtesy of Dr. E. F. DuBois*)

Express height in centimeters by dividing height in inches by 0.394. Express weight in kilograms by dividing weight in pounds by 2.2. Place a ruler horizontally at the point corresponding to height in centimeters and another vertically at the point corresponding to body weight in kilograms. Where these two intersect place a dot. If this dot falls upon one of the curving diagonal lines, read the surface in square meters from the end of the line. If it falls between two lines estimate the distance on a line between them and perpendicular to them. Thus if the point falls midway between 1.6 and 1.7 the surface area will be 1.65 square meters.

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